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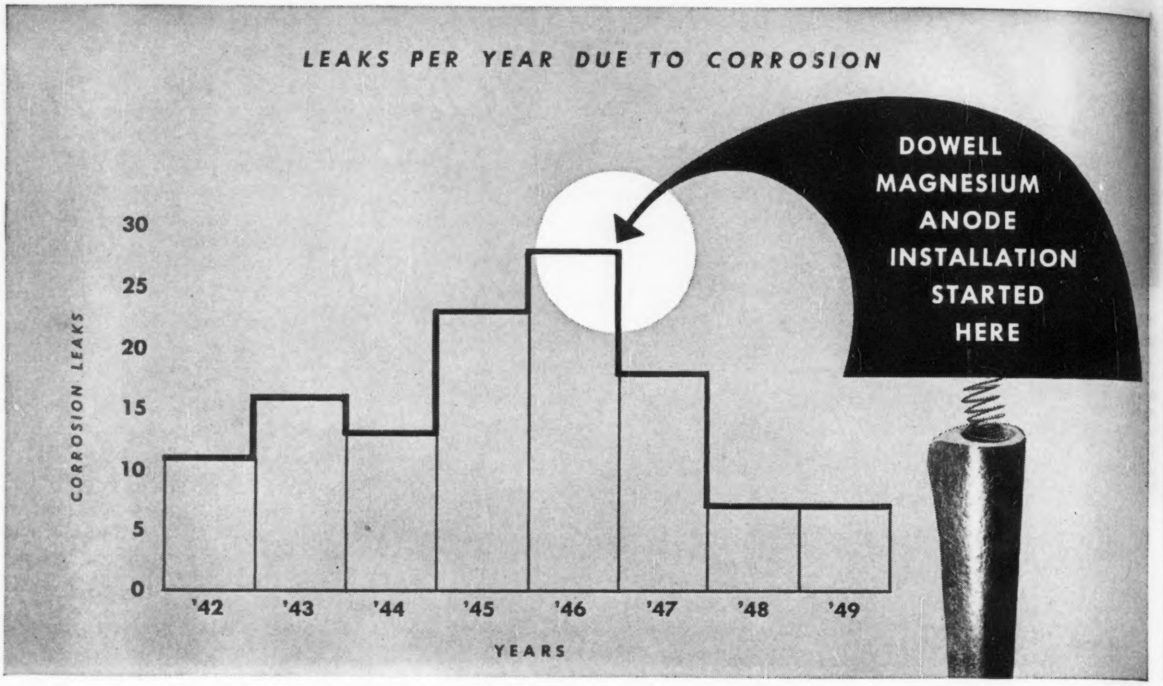
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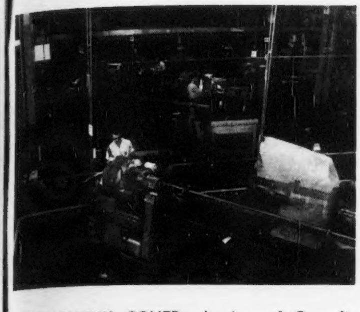

THIS MONTH'S COVER—A view of Consolidated Vultee Aircraft Corp. shops, showing "good housekeeping" cited as one of the means of preventing corrosion used by this firm. N. H. Simpson, Chief Chemist at Consolidated's Fort Worth, Texas, plant refers to the value of cleanliness in protecting precision parts in his article in this issue "Causes of Corrosion in Airplanes and Methods of Prevention." The photograph is Figure 5 from his paper.

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☆

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CORROSION

Research and Control

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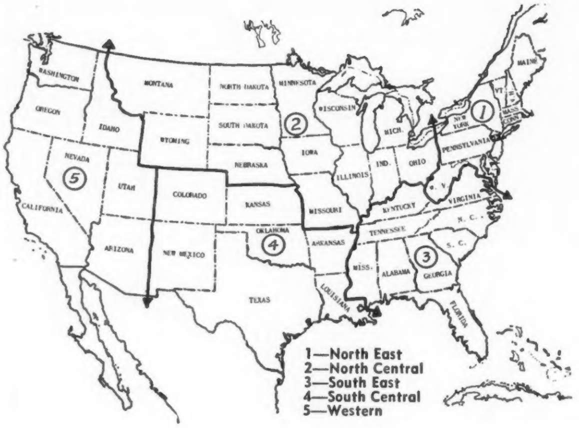

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AN ECONOMICAL METAL
for resisting Corrosion, Erosion and Metal-to-Metal Wear

Ni-Resist* is the trade name of a high nickel cast iron – one of the most economical corrosion-resistant engineering materials ever developed.

Ni-Resist, mechanically similar to gray iron, and resembling austenitic stainless steel in many characteristics, provides a unique combination of properties at moderate cost . . .

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Ni-Resist resists corrosive attacks of *acids, alkalies* and *salts* to a degree unmatched by any other product of the cast iron industry. In strong corrosives it has 20 to 200 times the resistance of plain iron, and 5 to 50 times the resistance in mild environments.

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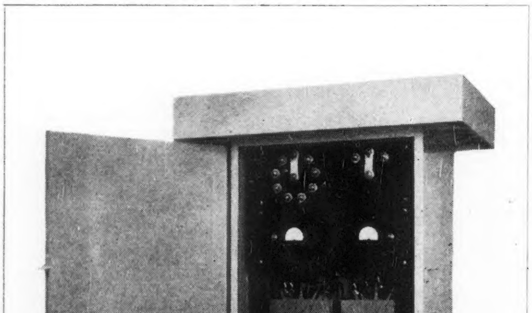

Technical Committee Activities

The Identification of Solid Corrosion Products

By C. M. SCHWARTZ*

A KNOWLEDGE of the identity of the crystalline phases which occur as corrosion products is an extremely valuable aid in the interpretation of the reaction mechanism. Unfortunately, the results of chemical analysis have frequently proved inadequate to identify the phases even though the element analysis is rather complete. X-ray and electron-diffraction methods have been applied with considerable success to phase identification in recent years. Reliable results can be rapidly obtained by these methods. The polarizing microscope is an older tool which is capable of providing important and frequently sufficient information for identification purposes, if the crystallite size is large enough to yield optical properties.

Diffraction methods of analysis depend upon a comparison of diffraction data from a polycrystalline sample with similar data from known pure chemical substances suspected to be present. The "standard" diffraction patterns act as "fingerprints" which serve to identify the unknown phases. A "fingerprint" file of a few thousand standard patterns is already available, and, through the efforts of a committee sponsored jointly by the American Society for Testing Materials, The American Society for X-Ray and Electron Diffraction, and the British Institute of Physics, the compilation is being continually expanded. The field of corrosion chemistry is, of course, included in this effort, but it naturally forms only a small part of the total coverage.

It is a common experience among diffraction workers to find the number of standards available in the file inadequate to cover a specific problem in the corrosion field. The pure compounds of interest as possible components of the corrosion system are frequently difficult to prepare. Committee TP-11 was activated this year to develop methods for the identification of corrosion residues. The diffraction method is the major consideration at present. The objective is to expand the file of standard diffraction patterns in the various corrosion systems. This effort will not compete with the activity of the ASTM Committee. All data which are collected will be turned over to the ASTM Committee, for general dissemination in the supplements which appear periodically.

The first requisite is a thorough canvass of possible sources of existing diffraction data, or known pure compounds, among the many laboratories interested in various aspects of corrosion. A questionnaire is now being prepared for distribution, requesting available but unpublished diffraction data. Just how effective such a request will be cannot be estimated.

The results of this survey will largely determine the scope of the activities of TP-11. It is rather certain that many gaps in different fields will be revealed. A breakdown of the subject is planned, on the basis of the common engineering metals and alloys together with their important corrosive media. It is expected that a coordinated program for the compilation of missing data can be laid out. The ultimate objective will be the acquisition of funds to carry out such a program.

Other identification techniques, in particular, the use of the polarizing microscope, fall within the scope of the Committee's activities, and have been considered. The formation of a subcommittee on identification methods was agreed upon as an eventual function of TP-11.

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* Batelle Memorial Institute. Chairman, NACE Technical Practices Committee TP-11, on Identification of Corrosion Products.

THE NATIONAL ASSOCIATION OF CORROSION ENGINEERS

is a non-profit, scientific and research association of individuals and companies concerned with corrosion or interested in it, whose objects are:

(a) to promote scientific research in determining the causes of corrosion and methods of its control with respect to theory and practice.

(b) to provide a means of exchange of knowledge and ideas among those individuals actively engaged in the control of corrosion.

(c) to promote methods of control of corrosion.

(d) to promote standardization of terminology, methods, equipment and design in the development of methods of corrosion control.

(e) to foster cooperation between individual owners of metallic structures in the solution of their joint corrosion problems.

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Neutralization as a Means of Controlling Corrosion of Refinery Equipment[★]

By E. Q. CAMP[*] and CECIL PHILLIPS[*]

Abstract

This paper summarizes the results obtained by using neutralizers as a means of controlling corrosion of refinery equipment. The methods employed in injecting sodium hydroxide, ammonia, and lime are presented. The ammonia distribution system serving the refinery is described. Information is presented in detail on the results obtained on the use of ammonia in controlling corrosion of equipment in connection with distillation, cracking, gas absorption, debutanization and steam systems. The injection of sodium hydroxide and lime into cracking units is discussed as well as the use of sodium hydroxide and soaps in controlling corrosion of distillation equipment.

Introduction

THE PETROLEUM refining industry is confronted with many peculiar and complex corrosion problems. This results largely from the number and variety of processes employed in the modern refinery. Since the general subject of corrosion of refinery equipment is too broad to be discussed adequately in a single paper, the present article is limted to a discussion of neutralization as a means of corrosion control. The information presented is a summary of the experiences obtained in using neutralizers in mitigating corrosion at the Baytown refinery of Humble Oil and Refining Company.

Corrosion control by chemical neutralization has been discussed in a number of papers published during the past several years.[1 thru 26] Although the present article is limited primarily to experience in one refinery, it is emphasized that they probably closely parallel those in other refineries in which neutralizers are used.

Causes of Corrosion

The following brief summary of some types of corrosion normally experienced in refinery equipment is presented to establish a basis for the discussion on the use of neutralizers.

The corrosion of refinery equipment occurring below about 500° F is ordinarily classified as low-temperature corrosion, while that which occurs above this temperature is normally considered high-temperature corrosion. The presence of water is usually essential to low-temperature corrosion, but is not considered particularly important at high-temperatures. Inorganic salts may or may not affect both low- and high-temperature corrosion. Turbulence is an important factor at either temperature level.[27, 28]

Low-Temperature Corrosion

Low-temperature corrosion normally experienced in refinery equipment is due primarily to hydrogen sulfide, hydrogen chloride, oxygen, carbon dioxide, and water. Brief discussions of the corrosive media involved in low-temperature corrosion are presented below.

1. *Hydrogen-sulfide:* Corrosion by hydrogen sulfide presents a problem of considerable magnitude in the operation of a refinery. Both oxygen and water usually are considered accelerators of low-temperature corrosion by hydrogen sulfide and generally it has been concluded that both must be present before any appreciable corrosion can occur. It has been reported that the amount of corrosion experienced depends upon the ratio of oxygen to hydrogen sulfide.[28, 29]

2. *Hydrogen chloride:* The water solution of this gas, hydrochloric acid, is the most corrosive agent encountered in distilling and refining crude oils. It is formed as a result of the hydrolysis of magnesium and possibly calcium chlorides usually associated with crude oils. This type of corrosion constitutes an acute problem after most crudes have been subjected to the elevated temperatures normally encountered in distillation, cracking, and other processes. This is a problem, however, that can be reduced appreciably by the proper use of neutralizers.[1 thru 26, 28]

3. *Oxygen:* The presence of oxygen is usually considered necessary for any appreciable corrosion to occur at low-temperature. This applies particularly to hydrogen-sulfide corrosion. It has been reported that low-temperature corrosion by hydrogen-sulfide is very nearly proportional to the oxygen concentration up to approximately five percent by volume of oxygen. At higher concentrations of oxygen, the rate of corrosion increases at a relatively lower rate with increase in oxygen concentration.[27] Oxygen is an accelerator of hydrochloric acid corrosion, but its presence is not required for this type of corrosion to occur at an appreciable rate.

4. *Carbon dioxide:* Corrosion as a result of carbon dioxide in steam systems frequently causes considerable trouble in the refinery. This type of corrosion is particularly acute in reboilers, steam heaters, condensate return lines, etc. Carbon dioxide corrosion

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[★] A paper presented at the Fifth Annual Conference, National Association of Corrosion Engineers, April 11-14, Cincinnati, Ohio.

[*] Humble Oil and Refining Company, Baytown, Texas.

may be a minor factor in low-temperature corrosion of distillation equipment in those cases in which the crudes contain appreciable quantities of bicarbonates. Carbon dioxide is evolved at distillation temperatures, wth the result that carbonic acid is formed in the product streams when the temperature is reduced below the condensation temperature of water. The utilization of neutralizers is an effective means of controlling this type of corrosion.[27, 28, 29]

High-Temperature Corrosion

High-temperature corrosion of refinery equipment primarily results from sulfur compounds present in the crude oil. The presence of inorganic salts, mineral acids, and organic acids may contribute appreciably to this type of corrosion. Of the various sulfur compounds usually present in crude oils, it is generally agreed that free sulfur, hydrogen-sulfide, and mercaptans are the most corrosive under high-temperature conditions. The corrosion that occurs as a result of the presence of other sulfur compounds in crude oils is probably a consequence of the action of the products formed by the thermal decomposition of relatively non-corrosive sulfur compounds. Turbulence is probably the most important factor in corrosion of steel by sulfur compounds at elevated temperature, other than the concentration of the more reactive sulfur compounds themselves.[27, 28]

Methods of Combating Corrosion

The methods most commonly used in prolonging the life of refinery equipment include 1) additional thickness of metal, 2) more resistant metals and alloys, 3) protective linings, metallic or non-metallic, 4) inhibitors, 5) cathodic protection, and 6) alkaline neutralizers. It is customary practice in the operation of a refinery to use all these methods of prolonging life of equipment.

Neutralizers used in the Baytown refinery include ammonia, sodium hydroxide, lime, sodium salts of petroleum phenols, naphthenic soaps (mixtures of sodium naphthenates, sodium sulfide, sodium hydroxide, etc.), and triethanolamine. Results obtained by using these various neutralizers are summarized in the discussions that follow.

Ammonia

1) Storage and distribution: The ammonia storage system consists of five horizontal steel drums, each approximately six feet in diameter and 40 feet long. The combined storage capacity of tese five drums is approximately 200,000 pounds of liquid ammonia. About 1000 pounds of ammonia per day are used in the refinery for corrosion control. The distribution system consists of steel lines servicing the various processing units at which ammonia is used.

2) Crude distillation: The distillation of crude oils that contain appreciable quantities of salts is usually accompanied by rapid corrosion of vapor lines, condensers, and other equipment downstream from the distillation units. This corrosion is attributed to hydrochloric acid formed as a result of the hydrolysis of the magnesium and possibly calcium chlorides present in the crude charge. The vapor lines are of low-carbon steel. Frequently, naphtha vapor-to-crude exchangers are employed as a medium of heat exchange between the naphtha vapors and the crude charge. These exchangers are usually equipped with either admiralty metal or copper-nickel alloy tubes. The exchanger shells are usually of cast iron or steel. In some cases the final condensers and coolers are cast iron of the coil-in-box type.

It is common practice to inject ammonia into the vapor lines from the distillation columns to minimize corrosion in the vapor lines, in the condensing and cooling equipment, and in other downstream equipment. The pH of the water condensed with the naphtha is usually maintained at 6.5 to 7.0. Water is normally injected upstream from the ammonia-injection point to prevent the deposition of ammonium salts in the vapor lines and condensers. The necessity for injecting water depends upon whether or not steam is used in the distillation step. If adequate steam is used to dissolve the ammonium salts, the injection of water is not considered necessary. The maintenance of pH's in the order of 6.5 to 7.0 is adequate for the neutralization of mineral acids and most organic acids. If higher pH's were maintained, considerable quantities of ammonia would be consumed in the neutralization of hydrogen sulfide. This is not thought to be necessary to achieve adequate corrosion control.

The injection of ammonia into product streams from distillation units usually is controlled by manual adjustment of needle valves, using rotameters to measure the ammonia flow rate. The pH of the water condensed with the naphtha is in most cases measured at frequent intervals by means of comparators. In some cases recording pH meters are employed. More satisfactory corrosion control is obtained through the use of the recording pH meters. It is believed that even more satisfactory corrosion control could be obtained if automatic pH control and recording equipment were employed. This type of control is not in use at present, but may be employed in the future.

In crude distillation equipment, it is common practice to inject ammonia upstream from exchangers that are equipped with copper-bearing alloy tubes. It is normally assumed this practice would result in serious corrosion of the copper-bearing alloy tubes by the ammonia, particularly if the pH of the water were maintained above the neutral point. It has been found in practice, however, that this is not the case. This lack of corrosion of the copper-bearing alloys of ammonia is attributed to the inhibitive effect of hydrogen-sulfide, mercaptans, etc., on this type of corrosion.[9]

3) Steam heating systems: Shortly after starting up a new toluene plant at Baytown, severe corrosion was experienced in steam heated exchangers and in steam condensate systems. This corrosion was attributed to the high carbon dioxide content of the steam which was produced from untreated water having a high bicarbonate content. The dissolved oxygen content of this steam was less than 0.1 part per million. The service life on certain exchanger bundles in this plant was limited to about two motnhs because of severe corrosion of the steel tubes contacted by the

hot (250° to 300°) 150-pound steam condensate containing 80 to 120 parts per million of carbon dioxide. The use of acid-treated softened water was considered the most satisfactory immediate scheme for alleviating this corrosion because the treated water could be obtained from an existing water treating plant. This scheme was adopted pending a laboratory investigation of corrosion inhibitors and neutralizers that might be applicable to this problem.

In the laboratory studies corrosion rates were measured on steel test strips exposed to steam condensate. This condensate was produced by distilling water to which had been added sufficient sodium bicarbonate to give approximately 100 parts per million of free carbon dioxide in the condensed steam. Various amounts of ammonia were added to the steam from the "synthetic" boiler feed water to determine the effectiveness of this neutralizer in reducing the corrosiveness of the carbonic acid. Figure 1 shows the results of corrosion rate measurements on steel in steam condensate containing carbon dioxide with the pH adjusted to various values by the addition of ammonia. As a result of these studies, the injection of a dilute aqueous solution of ammonia into the main steam line to this plant was started. Sufficient ammonia was added to maintain the pH of the steam condensate in the range of 8.5 to 9.0. The use of ammonia in the steam to this particular plant was considered to be harmless because the steam would not come in contact with any copper-bearing alloys, and the small amount of condensate which is recovered passes through a deaerator before returning to the boilers. Figure 2 is a schematic drawing of the ammonia mixing and injection system, while Figure 3 is a picture of an aqueous ammonia injection system now in use at the Baytown refinery.

Corrosion test strips were placed in the steam condensate system before and during the use of treated boiler feed water and during the injection of ammonia into the steam. Corrosion rates measured on these test strips indicated that the use of treated water instead of raw water in the steam generating plant resulted in a 56 percent reduction in the corrosion rate on steel in the condensate system. When using treated water plus ammonia injection to adjust the pH of the condensate to 8.5 to 9.0 the corrosion rate of steel was reduced 92 and 96 percent based on the rates obtained when using treated and raw water, respectively, in the boilers.

No significant corrosion difficulties have been experienced in the steam system at this plant during the five and one-half years that ammonia has been used.

Ammonia injection systems similar to the one just described have been used to prevent corrosion in steam coils and suction heaters in large storage tanks for asphalt and various finished and unfinished lube oil stocks.

4) Thermal cracking units: In the operation of thermal cracking units, hydrochloric acid is produced as a result of thermal decomposition of magnesium and possibly calcium chlorides present in the charge. Organic acids also are formed in the cracking step. These include formic, acetic, and proprionic acids. These acids leave the units in the naphtha stream and cause considerable corrosion in the overhead vapor lines, in condensing and cooling equipment, and in other equipment downstream from the cracking units.

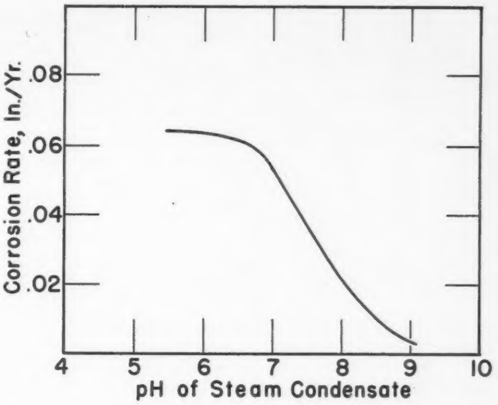

Figure 1—Corrosion rates on steel in steam condensate with pH adjusted by addition of ammonia.

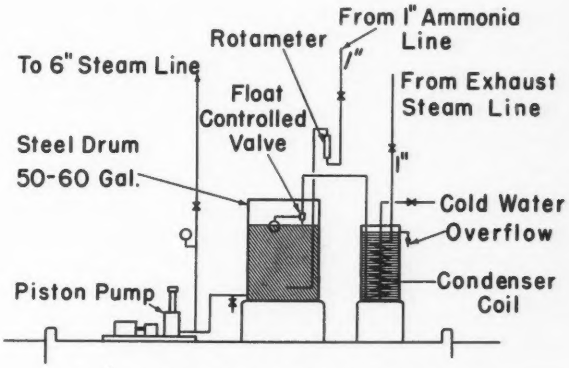

Figure 2—System for injection of ammonia into steam.

The pH of the water condensed with the product streams from units charging crude oil was in the order of 3.0 to 4.0. The water condensed with the product streams from units charging virgin gas oil and light cycle gas oil from thermal cracking ranged from 4.0 to 5.8. The water from units charging residue and a pH of 4.7 to 7.0. The combined water from the naphtha streams from all the thermal cracking units had a pH of from 4.0 to5.5. It is believed these pH values do not reflect the maximum acidity of the water at or near the point of condensation. The samples were taken for pH measurement after the water had passed through several hundred feet of condenser coils and steel lines. Some of the water samples contained several thousand parts per million of iron, indicating that a high percentage of the acids had reacted with iron. In effect, the pH measurements were made on waters containing large quantities of iron salts and probably a small quantity of the original acidic materials as such.

Aqueous ammonia is injected into the vapor lines from the cracking units to neutralize the inorganic

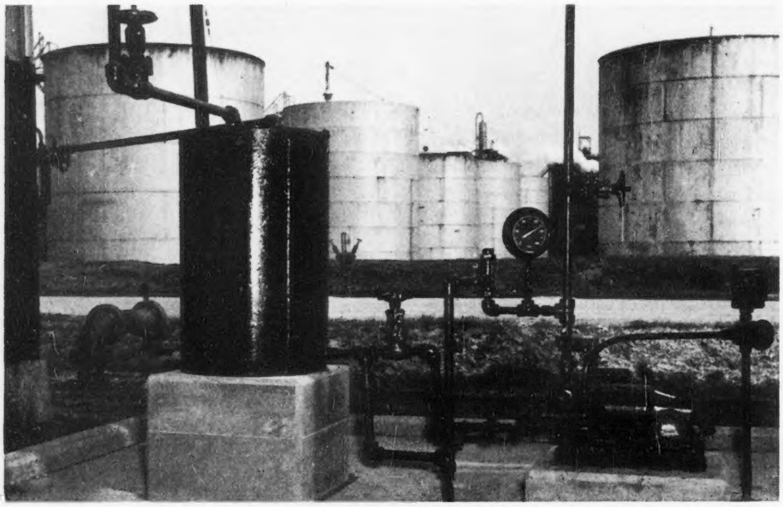

Figure 3—Aqueous ammonia injection system.

and organic acids produced in the cracking step and, thus reduce the corrosion of the various portions of equipment involved in condensing, cooling, transferring, and processing the cracked naphthas. The ammonia is injected in the form of a dilute aqueous solution because the operating pressure on the vapor lines is in the order of 80 pounds per square inch gauge. This pressure is above the vapor pressure of ammonia under year-round atmospheric temperature conditions. It is not considered practical or safe to apply heat to the ammonia storage drums and distribution system in order to raise the pressure of the gaseous ammonia to the level required for injection into this system. The aqueous ammonia injection system is similar to that already described for steam systems. The ammonia solution is metered into the vapor product lines from the cracking units by means of rotameters.

The pH of the water condensed with the naphtha from the cracking units has varied from 7.0 to 8.6. Corrosion of the equipment downstream from the points at which the ammonia solution is injected has been reduced appreciably. The iron content of the combined water from the naphtha stream from all the thermal cracking units is low.

5) Gas absorption unit: The gas absorption unit equipment employed in the recovery of gasoline fractions normally present in the wet gases produced in the various refining processes includes two series of absorption towers; namely, one in which the wet gases (chiefly from thermal cracking units) are passed countercurrent to the absorption oil at a pressure of approximately 65 pounds per square inch gauge, and the other in which the wet gases from various sources (crude distillation storage tanks, etc.) are passed countercurrent to the absorption oil at a pressure of approximately 45 pounds per square inch gauge. The rich absorption oils from these two systems are mixed and denuded of the absorbed gases in two stripping stills (primary and secondary) operated in series. The lean absorption oil from the bottom of the secondary still is recirculated to the absorption towers.

Considerable difficulties were experienced at this plant as a result of rapid corrosion of the steel vapor lines, condensers, and other equipment downstream from the primary and secondary towers. The tubes in the condensers are of admiralty metal.

The waters condensed with the product streams from the primary and secondary towers had a pH of from 3.5 to 4.5. Analyses of these waters indicated the acidity was the result primarily of organic acids, although traces of mineral acids were in evidence. It is postulated that most of the organic acids were formed in the absorption unit. This is particularly true of the low pressure system in which the wet gases to the unit contain appreciable quantities of oxygen. It is indicated that the mineral acids (principally hydrochloric) and perhaps some of the organic acids enter the absorption system with the wet gases.

Aqueous ammonia is injected into the reflux line to the secondary tower to protect the top portion of the tower vapor lines, condensers, and other equipment downstream from this point. The ammonium salts formed in the tower are washed out with water that is withdrawn from the fourth plate from the top of the tower. Only a small amount of water is condensed in the top of the primary tower. As a result, the corrosion in connection with this tower is limted primarily to vapor line condensers, and other equipment downstream from these points. The ammonia solution is injected into the vapor line from the primary tower. The pH's of the waters withdrawn from the secondary tower and from the overhead accumulators of both towers are maintained in the order of 6.5 to 7.0. This type of control has effected an 80 to 90 percent reduction in the corrosion of the equipment involved at this plant. The use of ammonia at this plant has not had any corrosive effect on the copper-bearing alloy tubes because sufficient hydrogen sulfide and other sulfur compounds are present to inhibit this type of corrosion.

The aqueous ammonia injection system used at this plant is similar to that already described in connection with corrosion in steam systems.

6) Acid oils: Ammonia has been used with success in neutralizing an oil after treatment with sulfuric acid to render it non-corrosive to lines, tanks, and distillation equipment. The ammonia was injected in the liquid state into the oil from the acid treating step. Ammonia was evolved in the distillation step and gave almost complete protection of the distillation overhead equipment.

Sodium Hydroxide

1) Crude distillation: The injection of sodium hy-

droxide solution into the crude charge to two pipe stills is now in practice at Baytown. In the first case, crude oil is reduced to about 40 percent bottoms. The bottoms from this operation are cracked in a thermal cracking unit. In the early operation of this pipe still, rapid corrosion of the furnace tubes, overhead lines, and condensers was experienced. The first step in reducing this corrosion involved the injection of sodium hydroxide solution into the crude charge. The injection of caustic solution equivalent to 6 pounds of sodium hydroxide per 1,000 barrels of crude oil materially reduced the corrosion of the furnace tubes and the overhead equipment of the pipe still. Larger amounts of caustic progressively reduced corrosion of the pipe still equipment, but limited operations at the residuum cracking units because of the rise in tube-metal temperature of the cracking coil furnace tubes. The injection of caustic with crude effected a marked reduction in the amount of hydrochloric acid evolved in the distillation step, but did not eliminate it. As a result, ammonia is injected into the overhead vapor line as a further precautionary measure against corrosion.[28]

In the operation of a second pipe still, considerable difficulty was experienced as a result of corrosion and deposition of salts on the crude side of exchangers in the preheat system. The injection of 0.07 to 0.16 percent by volume of water into the crude charge at the suction of the charge pump effected a marked reduction in the rate of deposition of salts in the exchangers, but increased the corrosion of the exchanger tubes. Prior to the injection of water, the life of the admiralty tube bundles was in the order of 29 to 36 months. After the injection of water was initiated, the life of the tube bundles varied from 3 to 19.5 months. It was found that the corrosion of these tube bundles was caused principally by hydrochloric acid formed as a result of the hydrolysis of magnesium and possibly calcium chlorides. In order to control this corrosion, dilute sodium hydroxide solution equivalent to 1.5 pounds of NaOH per 1,000 barrels of crude was injected into the crude along with the normal amount of water. The injection of this amount of caustic essentially eliminated the corrosion of the tube bundles. The life of the tubes after the injection of caustic was in excess of that prior to the injection of water. In addition, the injection of caustic resulted in the maintenance of scale-free surfaces on the exchanger tubes.

2) Thermal cracking: Reduced crude from a pipe still operation is cracked in a partial-yield operation on a thermal cracking unit. It has been found that the injection of caustic, 6 pounds per 1,000 barrels of crude, into the crude charge to the pipe still resulted in an appreciable reduction in the corrosion of the thermal cracking unit in which the residuum from the pipe still is processed. Larger quantities of caustic could be tolerated in the pipe still, but any increase in the amount of caustic injected into the charge to the pipe still materially affected the service factor on the thermal cracking unit as a result of the rapid rise of metal temperatures in the furnace tubes.[28]

3) Acid oils: It is common practice to caustic wash all oils after acid treatment, SO_2 extraction, etc. This renders these oils essentially non-corrosive to tanks, lines, distillation equipment, etc. Some acid oils are redistilled over caustic or other alkaline materials to prevent corrosion from acidic materials released at distillation temperature.

4) Sulfide bearing oils: Caustic washing of distillates from sour crudes has effected an increase of 5.4 years in the average life of tank roofs in rundown and intermediate storage service.[28]

Lime

An experimental study was made to determine whether the corrosion of cracking equipment could be reduced by injecting lime ahead of the cracking-unit furnace. It was found that, when injecting 250 pounds of lime per 1,000 barrels of residua, the life of the steel tubes in the convection section of the cracking unit furnace was increased by about 40 percent, and the overall loss of iron from the unit was decreased by 20 to 30 percent. The injection of lime was never put into practice, because the increase in sediment content of the fuel from the cracking operation was more than could be tolerated.[28]

Partially Neutralized Petroleum Phenols

In distilling alkylate produced in a sulfuric-acid process, rapid corrosion of the preheaters, reboilers, distillation columns, and overhead equipment was experienced. This corrosion resulted from sulfur dioxide and probably other acidic materials evolved in the decomposition of esters at distillation temperature. The corrosion of this equipment was essentially eliminated by injecting from 80 to 100 gallons per day of 50 percent neutralized petroleum phenols into the alkylate stream immediately ahead of the distillation equipment. Other alkaline materials were tried in connection with this problem, but they were not particularly effective because they were insoluble in the total alkylate stream and separated from the alkylate in various portions of the distillation equipment. The partially neutralized petroleum phenols have the property of being somewhat miscible with the alkylate and as a result give almost complete neutralization of the acidic materials as they are released under distillation conditions.

Naphthenic Soaps

Soap bottoms produced in distilling crude oils in the presence of sodium hydroxide for the removal of naphthenic acids have been found to be very effective for use in neutralizing acidic materials released in some distillation processes. These soap bottoms contain a mixture of sodium naphthenates, sodium sulfide, sodium hydroxide, etc. A typical example of the use of this alkaline neutralizer is in connection with redistilling an oil after treatment with sulfuric acid. This distillation operation is carried out on a battery of shell stills. Sulfur dioxide is released in this operation with the result that the overhead equipment is corroded at a rapid rate without the use of a neutralizer. The soap bottoms are injected into the charge to this battery. The available alkalinity in the soap bottoms neutralizes the sulfur dioxide and prevents its escape with the overhead products. These soap bottoms are relatively oil-soluble and for this reason give more complete neutralization than could be obtained with sodium hydroxide, which settles out in the stills and results in high metal temperatures. An added advantage of the soap bottoms is that they can be used as a carrier of additional caustic and still be somewhat miscible in oil. The excess caustic and salts are withdrawn from the rerun stills with the bottoms without materially fouling the still bottoms themselves.

Triethanolamine

In a thermal polymerization plant in which butane and propane are polymerized at high temperature and pressure for the production of gasoline, a severe corrosion problem developed in product condensers and piping when one of the charge streams became contaminated with a small amount of methyl chloride. The methyl chloride decomposed at the high temperature in the furnace, producing hydrogen chloride. At points in the distillation equipment where condensation of water in the overhead product stream first occurred, the hydrochloric acid formed resulted in dropping the pH of the water to approximately 2.5. Rapid metal loss occurred in steel equipment at these points. After considering several alkaline materials as possible neutralizers to combat this corrosion, triethanolamine was selected as the most advantageous. This material is a highly alkaline and relatively non-volatile liquid and is completely miscible with water. The triethanolamine was diluted to approximately two percent solution with water and the dilute solution was injected into the overhead vapor line by means of a small variable stroke piston pump. Sufficient neutralizer was injected to maintain the pH of the condensed water at 7 to 8. Corrosion of the steel equipment has been essentially eliminated by this procedure. Condenser tube bundles of admiralty metal handling the overhead stream containing triethanolamine have experienced no corrosion.

Acknowledgments

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DISCUSSION

Question by James R. Harrison, The Pure Oil Co., P. O. Box 951, Newark, Ohio:

Have you any experimental data that shows the influence of sulfide concentration on the amount of NH_3 which it is necessary to inject in fractionator overhead streams to obtain effective neutralization? Is NH_3 addition based on total S or on the concentration of, say, H_2S, RSH and R_2S_2?

Authors' Comment:

In laboratory neutralizations of aqueous hydrogen sulfide solutions with ammonium hydroxide the quantities of ammonia required to obtain various pH's are shown in the table below. In this titration the hydrogen sulfide solution contained .0245 gm. mols H_2S per liter. This is the concentration calculated to be in equilibrium with a gas containing 10 percent H_2S under 15 lbs. per sq. in. gauge pressure and at 18° C. The titration data for a solution containing only one-tenth this concentration of H_2S

were practically identical with those shown for the more concentrated solution.

Ratio $\frac{\text{Mols NH}_3}{\text{Mols H}_2\text{S}}$	pH of Solution
.025	5.5
.085	6.0
.23	6.5
.48	7.0
.76	7.5
.94	8.0

Since the ratio $\frac{\text{Mols NH}_3}{\text{Mols H}_2\text{S}}$ is independent of H_2S concentration within reasonable limits, the ratios shown may be used to estimate the quantity of ammonia consumed in neutralizing hydrogen sulfide in crude distillation overhead streams if the hydrogen sulfide concentration in the overhead water is known. This quantity of ammonia is over and above that required for the neutralization of hydrochloric acid. No information is available on the effect of mercaptans and disulfides on ammonia consumption.

Comment by A. W. Tracy, The American Brass Co., Waterbury, Conn.:

We have exposed hard drawn shells of 65-35 brass to vapors of hydrogen sulphide and ammonia formed by the hydrolysis of ammonium sulphide solution and have found that the presence of the sulphide inhibits stress-corrosion cracking of the stressed brass.

When ammonia is added to overhead vapors to prevent corrosion of the iron or steel equipment, most of the ammonia combines immediately to form ammonium chloride or other ammonium compounds so that when the vapors reach the condensers and come in contact with admiralty tubes, very little free ammonia remains and stress-corrosion cracking is not considered a serious problem. On the other hand, when soda ash or caustic soda solutions are injected into the overhead vapors, the ammonia in any ammonium compound that may be present will be set free and may cause stress-corrosion cracking of admiralty tubes.

Authors' Reply:

Laboratory corrosion tests on admiralty strips exposed to aqueous 10 percent ammonium hydroxide solutions gave reductions in corrosion rates of 94 percent when only 0.025 percent ammonium hydrosulfide was added to the solution, and 89 percent when 0.5 percent butyl mercaptan was added to the solution. It is felt that these test results in solutions containing an obvious excess of ammonia indicate that the reduction in corrosion and cracking of brass in overhead vapor condensers on crude distillation equipment is actually due to the inhibiting effect of the sulfur compounds, rather than the removal of ammonia by reaction with hydrochloric acid. The possibility of stress-corrosion cracking of brass occurring due to the evolution of ammonia from ammonium compounds by the addition of soda ash or caustic soda to the distillate is thought to be remote unless the alkaline solution added also removes the inhibiting sulfur compounds.

Comments by George N. Perkins, Esso Standard Oil Co. of Louisiana, Baton Rouge, La.:

At Baton Rouge crude distillation unit atmospheric overhead streams, the lower pH limit of the water drawoff has been set at 6 to provide against acid corrosion of carbon steel, and the upper limit has been set at 8 pH to minimize the possibility of stress corrosion cracking and general corrosion of admiralty tubes in condenser and exchanger bundles upstream of the water drawoff point. It is not believed that these limits are necessarily optimum. The upper pH limit is in doubt because hydrogen sulphide has been reported by Humble to successfully inhibit the stress corrosion of admiralty and because it has not been established (to our knowledge) whether admiralty is more susceptible to stress corrosion in ammonia atmospheres at pH's above 8 than at pH's between 7 and 8. Since the reaction of hydrogen sulphide with iron is believed to take place at pH's as high as 10, the lower limit is also in doubt.

Use of 70-30 copper nickel or other alloys instead of admiralty tubes may change the optimum pH limits for this stream.

It is desired to know if the optimum pH limits for crude distillation overhead streams has been established for units with admiralty overhead condenser bundles and for units with 70-30 copper nickel overhead bundles.

Authors' Reply:

The optimum pH limits have not been established for corrosion control of admiralty or other copper bearing alloy overhead condensers on crude distillation units. The upper pH limit of 7 was established at the Baytown Refinery in the interest of conserving ammonia, since ammonia consumption rises rapidly as higher pH's are maintained.

Comments by Curtis W. Cannon, The Frontier Chemical Co., Denver City, Texas:

The question of what governs the choice of caustic soda or lime for injection into cracking furnace charges was asked by the writer. The author of the paper had cited instances where caustic soda was used and other instances where lime was used to prevent furnace corrosion. He also stated that high BS&W resulted where lime was used as a corrosion preventive. This remark seemed to indicate the caustic soda would be preferable additive since it would result in much lower BS&W in the residual fuels. The author of the paper and some members of the audience cited instances where there had been more furnace coking trouble experienced with the use of caustic soda in the oil charge than was the case in the use of lime.

Authors' Reply:

It has been our experience that caustic soda may be used satisfactorily in crude still furnaces operating with coil outlet temperatures up to 575° F, whereas, considerable fouling is encountered as a result of using caustic soda in cracking furnace tubes operating at coil outlet temperatures of 900° F. As a result of this experience it is our opinion that caustic soda cannot be used satisfactorily as a neutralizer for corrosion control in thermal cracking furnaces. The possibility of using lime for this purpose would depend upon whether a large increase in the sediment content of the residual tar could be tolerated.

Comments by F. N. Speller, Consultant, Pittsburgh, Pa.:

About 1933 ammonia was added to the water in a low pressure closed steam heating system, at National Tube Company's laboratory, Pittsburgh, Pa. The condensate was thereby brought to pH 9 in the fall and by the following spring, without further additions it had a pH about 7.4, as I recall. No trouble due to corrosion was experienced with the brass or steel in this system while under this treatment for 10 years.

Comments by Nathan Schofer, Ebasco Services, Inc., New York City:

The Cities Service Refinery at Lake Charles, Louisiana has been using anhydrous ammonia in its two topping units for mitigation of corrosion since the plant was put into operation. Subsequently, ammonia injection has been added to the Thermal Reform and Cracking Unit.

Initially the neutralizing agent was injected into the overhead vapor lines; however, considerable corrosion of the top section of the towers and internals was experienced. The injection point was then changed to about the 8th tray down. Some difficulty was experienced with the deposition of ammonia salts, but this did not seriously affect operation. However, the installation of desalting equipment greatly reduced this problem.

Manual control of the injection was not satisfactory because the pH might vary from 3 to 9, although it was normally kept between 6.5 and 7.5. The recent installation of automatic controlling and recording equipment has effectively solved this problem, so that the pH is kept within ± 0.02 without any difficulty.

Comments by R. T. Effinger, Shell Oil Co., Inc., Martinez, Cal.:

Experience at the Shell Oil Company's Martinez Refinery with alkaline neutralizing agents has indicated that sodium carbonate causes less fouling of heat transfer surfaces that equivalent amounts of sodium hydroxide. For example, in a distilling unit used to redistill acid-treated cracked distillate, large quantities of sodium carbonate are used to neutralize acidic compounds which are liberated from the hydrolysis of sulfonates in the feed stream. The exit temperature from the heaters in this unit is approximately 460°F and salt deposition on the tubes is negligible when soda ash is injected into the feed at a rate of 25 to 45 pounds per thousand barrels. When the stoichiometric equivalent of sodium hydroxide has been substituted for sodium carbonate, severe fouling of heater tubes and heat exchangers has occurred.

An Alternate to Lead Sheath for Telephone Cables★

By *ANTHONY PAONE**

Abstract

In order to permit rapid expansion of telephone cable production to meet unprecedented postwar requirements, a new type of sheath was developed as an alternative to lead-antimony sheath for paper insulated exchange type telephone cables. Moisture protection for the dry core is provided by a combination of corrugated aluminum, a flooding of moisture resistant cement and an outer polyethylene jacket. The impracticability of obtaining sufficient lead to keep pace with the increasing core production made it necessary to introduce the new sheath. The new cable offers possibilities as an alternative to lead sheath cable with corrosion protection for use in conduit and also affords a means of effecting distributed forced drainage to minimize corrosion on paralleling plain lead covered cables.

VARIOUS TYPES of protective coverings have been used on lead sheath of telephone cables in the past twenty years as a means of preventing electrolytic or chemical corrosion of the lead.[1] In recent years, a considerable amount of lead sheath cable with protective coverings has been used in conduit. In the latter case the protection consists of a flooding of asphalt over the lead followed by wrappings of sisal kraft paper and fabric each of which is flooded with asphalt. The completed coating is finished with whiting to prevent sticking of adjacent turns of the cable on the reel, and for ease of installation. Cable of the latter type has been used largely in areas where experience with bare lead covered cables has been unfavorable or where other means could not be employed to ensure the serviceability of unprotected lead sheath.

The advantages of having a non-metallic sheath to preclude corrosion of underground telephone cables have been recognized for many years and various attempts have been made to work out a suitable design. With the materials available heretofore, it has

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★ A paper presented at the Fifth Annual Conference, National Association of Corrosion Engineers, Cincinnati, Ohio, April 11-14, 1949.

* American Telephone & Telegraph Co., 195 Broadway, N.Y. 7, N.Y.

not been practicable to produce such a sheath. However, advances made in plastics since the beginning of the war combined with developments stemming from the serious shortage of lead, have resulted in a plastic sheath of considerable promise which not only solves the corrosion problem, but affords a new means of mitigating corrosion of existing lead sheathed cables. Exchange type cable with the new sheath has been manufactured in large quantity during the past 18 months. This sheath contains no lead. It consists of circumferentially corrugated aluminum with a longitudinal overlapped and cemented seam covered with a flooding of viscous cement and an extruded polyethylene jacket. Based on the limited experience to date this type of cable appears to be a promising alternative and is more economical than corrosion protected lead sheath cable and may eventually supplant the corrosion protected type. The design of this special sheath cable has many features which are of interest to the corrosion engineer and it seems appropriate, therefore, to review the factors leading to its introduction, discuss the design as it affects the serviceability of the core conductors and consider the various features of the design which are of particular interest in corrosion mitigation.

Factors Leading to Introduction of New Sheath

Lead sheath has many characteristics that over the years have made it a nearly ideal covering for telephone cables. The material is homogeneous and relatively easy to apply to a cable core. The finished cable is pliable and can be formed readily in manholes. Lead has a fair degree of mechanical strength which makes pulling into ducts relatively simple. In most environments unprotected lead sheath resists corrosion extremely well. Lead sheath cable lends itself to the use of wiped soldered joints in hermetically sealing the conductors and insulation at splices. Of the available metals, lead has qualities which have not been equalled by other metals as a cable sheathing material.

The unprecedented postwar demand for telephone cable and consequent necessity for rapid expansion of cable production facilities combined with the shortage of lead and uncertainties of future supply were major factors leading to the introduction of substitute coverings for cables.

Perhaps the most serious shortcoming of lead in aerial cable is its tendency to fatigue from vibration as well as alternate expansion and contraction due to temperature changes. The standard lead-antimony alloy is better than plain lead in this respect, but there has been a feeling that an alternative sheath might be developed which would prove superior to either for aerial use where fatigue is an important maintenance factor.[2]

From the standpoint of moisture resistance, plastics and other organic compounds so far available do not afford the protection necessary for paper insulated telephone cables. Also, electrical conductivity comparable to that provided by a lead sheath is desirable for magnetic shielding. In considering alternative designs, it was, therefore, necessary to make use of composite sheaths combining thin metal sections for moisture resistance, mechanical protection and conductivity with a thermoplastic jacket or filler. The first experimental substitute for lead sheath consisted of two layers of brass with a longitudinal soldered seam and transverse corrugations to provide flexibility; between these was a layer of rubber thermoplastic material. The first trials of such a cable were made in 1934. However, the design proved too expensive in comparison to lead covered cables. Further work resulted in a somewhat less costly design, by using corrugated steel with no solder over the core, covered with a layer of thermoplastic and an outer corrugated brass with a continuously soldered seam. The brass sheath cables had the disadvantage that their use would be confined to aerial plant because they were not suitable for underground use due to the possibility of corrosion. Experimental trials of this construction were made in 1941 following which the work was stopped because of the war.

Fortunately, during the war, considerable work had been done on plastic materials which had better mechanical properties and moisture diffusion resistance than the rubber thermoplastic available previously. A review of the plastics available led to the selection of polyethylene because of its resistance to diffusion of moisture, good mechanical and chemical properties,[3] and availability in the quantities required. As an interim design it was, therefore, decided to use over the core conductors a corrugated aluminum sheath with a water resistant cement in the overlap followed by a flooding of another cement and an extruded outer polyethylene jacket. This cable is referred to as Alpeth, a contraction derived from the words *al*uminum and *p*oly*eth*ylene.

Design Considerations

The moisture diffusion characteristics of the rubber thermoplastic compound used in the original composite sheath was such that a hermetically sealed outer metallic covering was considered necessary. Polyethylene provided much better resistance to moisture diffusion and experiments indicated that a relatively long life could be expected with a cable having an overlapped metallic barrier over the core with an outer polyethylene jacket. The corrugated metal is cemented at the overlap and a flooding of cement is applied over the metal to reduce voids and minimize moisture diffusion. Specimens of this cable have been submerged in water for about two years without appreciable moisture absorption by the paper insulation on the conductors. Because the cable is to be used aerially as well as underground, the polyethylene is compounded with carbon black to improve its behavior under long term exposure to sunlight.

Because the cable would be installed in standard bore conduit and in existing manholes, the outside diameter of the largest alpeth cable had to be reasonably close to that of the comparable lead sheath cable. Also, the bending characteristics had to be sufficiently like those of lead cable to permit setting up in a variety of manholes arranged to accommodate lead cables. Polyethylene jackets of 70 to 125 mils thickness, depending upon the cable diameter, were found necessary to provide the necessary mechanical strength. The necessary flexibility to permit winding the cable on reels and bending into position in manholes without damaging the aluminum was obtained by corrugating the aluminum transversely as it is applied. The resulting diameter of maximum size alpeth cable is 2.8 inches as compared to 2.62 inches for lead cable.

Field of Use

For underground application, the generally good resistance of polyethylene to chemical attack, light weight of the cable (approximately one-half that of comparable lead sheath cable), and resilience of the polyethylene makes pulling into ducts relatively easy and permits installation of long lengths with the cable in some cases drawn through intermediate manholes to reduce the number of splices necessary. Resistance to most chemicals is good, but some grades of polyethylene are subject to damage at points of high stress by soaps such as those used for lubrication in placing the cable and pressure testing to detect sheath faults. A water solution of a cellulose derivative is now being supplied for use in pressure testing splices in alpeth cable. A slurry of water and bentonite provides suitable lubrication during installation. Reinforcement of the sheath by friction tape wrappings in the bent sections in manholes reduces the tendency of the sheath to buckle where sharp bends are made in setting up the cable.

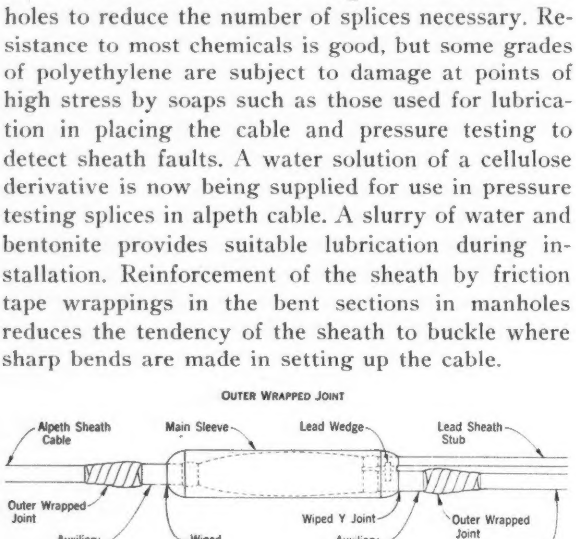

Figure 1

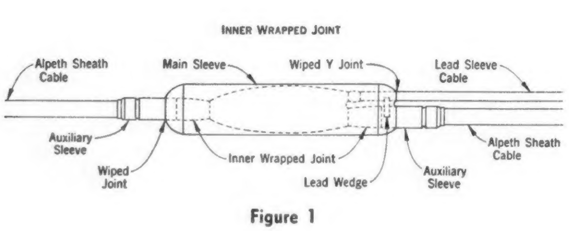

Figure 2

Polyethylene remains fairly tough up to temperatures of about 175° F but the material may be damaged if subjected to much higher temperatures. It begins to melt at about 220° F and is thus not resistant to fire or prolonged exposure to hot pipes or hot gases. The material burns when once ignited but the combustion is not rapid, nor will it progress along the cable through encircling cable clamps, lashed cable supports and the like. Because polyethylene will burn, alpeth cable is not used as risers in open shafts in buildings. It is, however, used in building conduit. Alpeth sheath cable has not been recommended for use at aerial crossings of steam railroads where hot exhaust gases could damage the cable sheath. Caution must also be used indoors where the cable is carried across boiler rooms or in the vicinity of steam pipes where the temperature might exceed 175° F.

Because of its corrosion resistant jacket and substantially lower price than lead cable with protective coverings, alpeth cable at first sight appears to be an attractive alternative to the usual lead covered cable with outer protection for buried use. However, there are offsetting factors. In buried cable, lightning strokes to the cable may fuse holes in the polyethylene and expose the aluminum envelope to soil corrosion. Lightning strokes to an aerial branch cable may result in current flow for some distance along the aluminum and create a potential to ground sufficient to puncture the polyethylene or break down the conductor insulation of the buried portion of the cable. These factors appear to limit its use as buried cable to lengths of only a few hundred feet, except where extensive underground services will provide the necessary shielding, as in the case of a compact housing development. However, as further experience is gained, it may be that it will find increasing use in buried plant in certain parts of the country.

Method of Splicing

At first it was thought that splices in the cable might be covered by wrapping them with appropriate tapes. However, it soon became evident that the required moisture protection at splices could be obtained more economically by means of lead sleeves, taped to the polyethylene sheath. In order to facilitate the wrapping operation and to permit entering splices for rearrangements without remaking the wrapped joints, an auxiliary lead sleeve is used on each polyethylene cable entering the splice. This arrangement also permits combining polyethylene and lead covered cables at one end of the splice, a requirement which arises frequently in existing plant. The two types of wrapped joints illustrated in Figure 1 are employed, the outer wrapped joint for cables that are not to be maintained under pressure, and the inner wrapped joint for cables under pressure. Figure 2 shows a cross-section of the auxiliary sleeve and outer type wrapped joints. The aluminum is made electrically continuous by means of bonding ribbon (6 ga. AWG equivalent) lashed and soldered to the aluminum. Because of the corrosive nature of fluxes normally used in soldering aluminum, the tinning is done by wire brushing the aluminum and rubbing molten aluminum solder on the cleaned area. Tinned bonding ribbon is then lashed in place over the solder and the connection is completed using an ordinary lead-tin solder.

A mechanical tie between the sleeve and polyethylene is obtained by soldering the lead sleeve to a layer of screen wire cloth which in turn is embedded in the polyethylene by applying heat with a soldering copper. The aluminum tape shown spanning the neoprene tape wrapping over the wire cloth serves to minimize moisture diffusion into the splice. Neoprene tape is used in the wrapped joint as it resists weathering and exposure to oils and other contaminants which may be found in manholes. Experience to date with the wrapped joints has been favorable.

Experiments indicate that aluminum polyethylene sheath cable can be sectionalized for maintenance under continuous pressure by means of wax and asphalt plugs made in much the same manner as plugs in lead covered cables. The compounds are introduced at somewhat lower temperatures to prevent damaging the polyethylene.

Bonding Arrangements

With lead sheath, the underground portion generally serves as the low resistance ground necessary for protection against lightning and accidental contacts with power circuits. Because the new sheath has an insulating jacket, it does not provide a low resistance ground. Therefore, when this cable is used the aluminum is bonded to the auxiliary sleeves at each end of the splice and the lead sleeve on the splice is bonded to any paralleling lead sheath cables in the manhole. If there is no paralleling lead sheath cable the ground connection is made where the Alpeth cable joins lead sheath cable, or by tying it to the central office ground.

If an insulating joint is required at the junction of an underground alpeth cable to an aerial alpeth or lead covered cable, it can be provided by omitting the bond between the aluminum and the auxiliary sleeve at the first splice in the underground section. Should it be necessary for noise reduction reasons to by-pass the insulating joint with an electrolytic condenser, the continuity of the aluminum should preferably be broken in the vertical section on the pole so as to facilitate installation of the condenser. In this case, the aluminum would be bonded to the auxiliary sleeve and to any other lead cables in the manhole.

Where insulating joints are required in the lead sheath cables at the central office vault, the aluminum-to-auxiliary-sleeve bond in the Alpeth cable is omitted in a convenient splice in the vault, to avoid short circuiting the insulating joints in the lead cables. Where there are a number of Alpeth sheath cables entering a vault, the bond connection among the various cables can be made by running a bus-wire lengthwise of the vault to permit making connections at the various splices. Insulated wire would be used if it is necessary to isolate the underground plant from the central office ground; otherwise, a bare conductor will suffice. Approximate bonding provisions can be made in a similar manner where there are separate entrances to a vault which require isolation or bonding for electrolysis protection purposes.

DRAINAGE DISTRIBUTED TO TWO POINTS

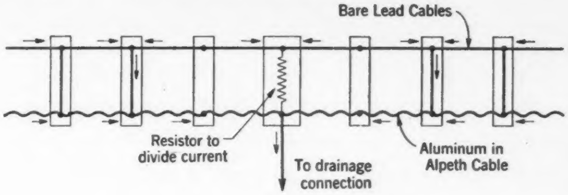

Figure 3

DRAINAGE DISTRIBUTED TO SEVERAL POINTS

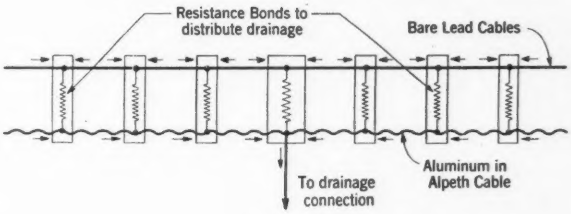

Figure 4

Use of Alpeth Sheath as an Insulated Drainage Conductor

The use of this cable in conduit is particularly attractive in non-stray current exchange cable areas if corrosion of lead sheath is an important maintenance factor. In such areas it provides an economical alternative to corrosion protected lead sheath cable. It also can be used to advantage in stray current areas where corrosion mitigation would otherwise require the installation of drainage wires or other protective devices.

Where the cable parallels existing bare lead sheath cables requiring drainage protection, the aluminum can be used as a conductor for applying distributed drainage to the lead sheath. The layout depends on the nature of the job at hand. Figure 3 and Figure 4 illustrate the general method of treatment. Figure 3 shows a condition in which the distributed drainage is effected by omitting the usual bonds from the aluminum to the lead sheath cables in the manholes between the drainage connection and the location where increased drainage is desired. Figure 4 illustrates how the drainage current may be distributed to various points along the lead sheath cable. The value of the resistors shown can be computed from test data or may be determined by trial. The relative conductivities of lead sheath and the aluminum in alpeth sheath of comparable core sizes are shown in Figure 5.

Conclusions

The introduction of Alpeth sheath has made it possible for the Bell System to overcome a serious postwar lead shortage and carry out the largest cable construction program in its history.[4] To meet the telephone companies' exchange cable requirements in

RELATIVE CONDUCTIVITY OF LEAD AND ALPETH SHEATHED CABLE

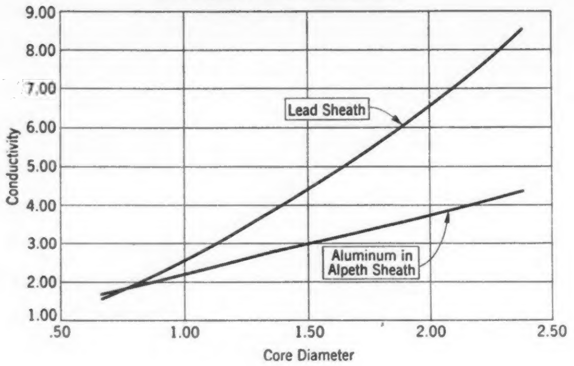

Figure 5

1948, it was necessary to manufacture exchange cable at a rate almost double that of the largest prewar year. Alpeth sheath is currently being used for 30 percent of the exchange cable made for the Bell System.

The successful introduction of this sheath makes available corrosion-free exchange area cable for use where cable with plain lead sheath or protected lead sheath is not altogether satisfactory. On account of the problem of adequate lightning protection under the conditions obtaining on long inter-city toll cables, this sheath has so far not been used for this purpose. Large quantities of lead sheath cable are, therefore, still being used for toll cables as well as a substantial part of the exchange area cables. Studies of polyethylene as a sheathing material as well as of manufacturing and installation techniques are being continued in order that the full potentialities of the new type cable sheath can be realized.

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1. Protective Coatings on Bell System Cables, V. J. Albano and Robert Pope. *Corrosion,* **3,** No. 5, 221-226 (1947) May.
2. Alpeth Sheath Cable, R. P. Ashbaugh. *Bell Laboratories Record,* **XXVI,** 442-444 (1948) Nov.
3. Selection and Application of Plastics, Bernard Mack. *Mats. and Meth.,* (1948) Sept.
4. Exchange Cable: The Drama of Postwar Production, Charles G. Sinclair, Jr. *Bell Telephone Magazine,* **XXVII,** 76-86 (1948) Summer.

DISCUSSION

Comment by L. F. Greve, Commonwealth Edison Co., 72 W. Adams St., Chicago, Ill.:

A recent experience with a polyvinyl chloride jacket over the lead sheath of a power cable may be of interest.

Severe cathodic corrosion of the lead sheaths had been experienced in a length of conduit in front of a car barn where salt was used during the winter months to keep the track switches from freezing. All of the cables in this conduit were replaced with jacketed cables about 10 years ago.

While pumping the manhole, bubbles were found to be coming through the fireproofing at a point about six inches from the joint. Inspection showed the bubbles to be coming from between the sheath and the jacket where the jacket had been terminated with a tape seal. The space between the jacket and the sheath was filled with a liquid which contained a high concentration of lead in the form of lead hydroxide. The liquid was a very strong alkali with a pH of about 12 and was under considerable gas pressure. The gas was probably hydrogen. This would indicate that the liquid entered through the jacket rather than at the ends.

The fact that the jacket itself appeared to be in good condition after 10 years service justifies its installation. The life of a lead sheath at this location is only about three years.

However, if a liquid will go through your Alpeth cable with a polyethylene jacket, under cathodic conditions, the aluminum will not stop the water from entering the core of the cable.

Author's Comments:

Because the electrical characteristics of dry paper-insulated telephone cable conductors would be seriously impaired by accumulation of moisture in the core, the possibility of such impairment was carefully considered in developing Alpeth sheath. One of the reasons for selecting polyethylene is that the rate of moisture diffusion through this material is low, for example, only about 1/20 of that through polyvinylchloride. Voids between the corrugated aluminum and the polyethylene jacket are kept to a minimum by flooding the aluminum with a thermoplastic compound just before the polyethylene is applied. A viscous compound is also applied to seal the overlap in the corrugated aluminum and thereby retard diffusion into the core of any small quantity of water vapor which may accumulate under the polyethylene. Periodic insulation resistance measurements for a period of over two years on the paper-insulated core of submerged Alpeth sheath cables, and laboratory measurements of moisture diffusion through Alpeth sheath indicate that the amount of moisture which is likely to enter the paper-insulated core through diffusion should have no significant effect on the service life of such cables.

Causes of Corrosion in Airplanes And Methods of Prevention★

By N. H. SIMPSON*

Abstract

In this paper the author endeavors to point out the varied types of corrosion which may occur on present types of aircraft and the latest methods of combating them. He also stresses the importance of continuous research into the corrosion problems of supersonic aircraft and missiles. At the same time some of the possible reactions that may occur at high speeds between the atmosphere and the aircraft or missiles' exposed surfaces are brought out.

AS A COMPLETE discourse on corrosion in aircraft is beyond the scope of any one article, no attempt is made in the following paragraphs to cover all phases of the subject. Instead only those of greatest importance will be discussed.

Aircraft, as is the case with all other transportation medium, always have been plagued by corrosion; however, in recent years the problem has become more acute because of extended demands placed on the metals. In the past metals with very low physical properties have been used, for the reason that alloys capable of developing high strengths were either non-existent, too hard to work, not favored by tradition or economically unsound. However, as soon as aircraft manufacturing became an industry, engineers began seeking with ever increasing vigor newer and better alloys with high strength-weight ratio. At first they were satisfied with steel that would produce an ultimate tensile strength of approximately 125,000 psi and aluminum alloys of 40-50,000 psi, but as the demands for speed and range increased the search for ever stronger metals was intensified until now the design ultimates are nearly double what they were a few years ago (Table I). This increase in strength has been obtained in some instances by development of new alloys, while in others the processing has been altered to cause changes in the metal which enhance its strength.

Castings in aircraft generally require large volumes of metal rather than high strength. This is primarily a consequence of their configuration. Large sections of the fuselage, in like manner, can be skinned with fairly low strength alloys, but these skins must be thick enough to have a fair degree of stiffness. Many other parts are of the same nature. For this reason when low density magnesium alloys were first developed, although most engineers were thinking of them primarily as material for fire bombs and sacrificial electrodes, aircraft engineers began experimenting with their use until today most of the castings and a large number of skins and other parts are made from this least noble of all structural alloys.

In this instance one of the many useful properties taken advantage of in magnesium is its great stiffness per unit weight; for example, a rod of magnesium of length and weight equal to one from aluminum and another of steel is four times as stiff as the aluminum and nineteen times as stiff as the steel.

Corrosion engineers have watched the progress of the various alloys with interest for it could mean one thing only to them — more and tougher corrosion problems. As the strength of the metals was increased, thinner sections were used; therefore, any corrosion which did occur would be more likely to cause trouble. Corrosion is no respector of strength, but will in general destroy no matter what the condition of the metal. Quite frequently the free energy of the metal is amplified by processing. When this occurs the tendency to react with its environment is increased. This characteristic was used at the Convair laboratories in development of a series of chemical spot checks to determine the type and condition of aluminum alloys.

Galvanic Trouble

Have you ever designed and assembled a part, finished it, and looked with elation upon the thing of beauty which you have created, and then set it out into the world to serve humanity? Then within a very short time your pride and joy was returned

TABLE I
Design Properties of Most Important Alloys Used in Aircraft

ALLOYS	Tensile Ultimate P.S.I.	Tensile Yield P.S.I.	Comp. Yield P.S.I.	Elongation Percent
Aluminum:				
52 SO	31,000	......	......	15—20
Clad 24 ST	56,000	37,000	37,000	13
Clad 24 SRT*	66,000	51,000	51,000	10
Clad 24 ST 80*	62,000	47,000	48,000	8
Clad 24 ST 81*	65,000	57,000	57,000	5
Clad 24 ST 84*	67,000	63,000	64,000	5
Clad 24 ST 86*	72,000	69,000	69,000	4
75 ST	74,000	62,000	62,000	7
Magnesium:				
Mh	32,000	24,000	18,000	4
Fs-1h	41,000	30,000	24,000	4
Steel:				
SAE 1025	55,000	36,000	36,000	22
X4130	150,000	135,000	135,000	12
X4340	200,000	165,000	165,000	5
Hy-Tuf	230,000	199,000	199,000	12

* These alloys are 24 ST improved by processing.

★ A paper presented at the South Central Regional Meeting, National Association of Corrosion Engineers, October 3-4, 1949, Dallas, Texas.

* Chief Chemist, Consolidated Vultee Aircraft Corp., Fort Worth Division, Fort Worth, Texas.

aged with a cancer-like growth which has rapidly disentegrated the work of art. If you have, then you know about galvanic corrosion. It is one of the most insidious types of diseases that afflicts metal. The author has seen improperly protected dissimilar metal assemblies made useless within 24 hours from this type of corrosion.

It is not uncommon in aircraft parts to see stainsteel, aluminum, copper, low alloy steels and magnesium used in dissimilar metal assemblies. This varied use of alloys present a rather difficult problem to the corrosion engineer (Figure 1). Especially is this true because the plane may be subjected to such a variety of environments. (Tables II and III.) The test from which the data was obtained in Figure 1 was made in order to determine the potenials that would exist between the various structural alloys listed and 75ST aluminum alloy in N/10 NaCl. From the results of this test it was concluded magnesium alloys, steels and bare manganese bronze must be well insulated from 75ST when used in dissimilar metal contacts.

Stainless steel is not quite as bad as the results indicate because the 75ST tends to polarize under normal conditions and stifle the corrosion. This reaction is anode controlled.

However, if halogens are present the galvanic corrosion will continue unabated until the aluminum alloy is destroyed.

Table II is interesting in that it shows the effect of different electrolytes on the solution potentials of metals. These particular electrolytes were chosen because they were typical of those to which most air-

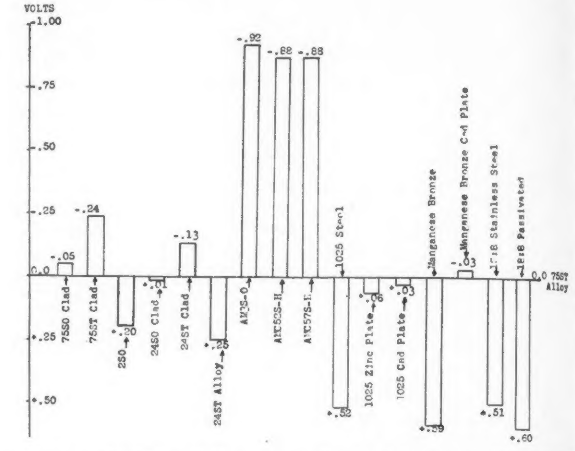

Figure 1—Potentials of the various alloys and tempers in N/10 NaCl referenced to 75ST aluminum alloy. 75ST is a relatively new alloy to the aircraft industry, consequently it was desirable to know what its solution potential is with respect to the other alloys.

TABLE II

Solution Potentials of Aircraft Alloys in Various Types of Natural Electrolytes

ALLOY	1/10 N. Sodium Chloride	Tap Water	Distilled Water	Lake Water	Sea Water	Rain Water	Primer Extract	Exhaust Condensate	Soil No. 1	Soil No. 2	Soil No. 3	Soil No. 4
2SO	+.26	+.20	+.26	+.18	+.12	+.30	+.38	+.49	+.15	+.16	+.28	+.20
24ST Dural	+.40	+.39	+.45	+.48	+.36	+.52	+.40	+.52	+.15	+.12	+.40	+.24
24ST 81 Dural	+.32	+.43	+.20	+.40	+.28	+.44	+.34	+.52	+.37	+.20	+.50	+.31
24ST Anodized	+.09	+.14	+.00	+.05	+.08	+.10	+.14	+.31	+.15	+.10	+.00	+.10
Clad 24ST	+.31	+.18	+.18	+.18	+.04	+.32	+.36	+.49	+.15	+.20	+.24	+.15
Clad 24ST-81	....	+.21	....	....	....	....	+.40	+.46	+.16	+.12	+.50	+.31
Clad 24SO	+.30	+.24	+.15	+.20	+.12	+.29	+.40	+.48	+.13	+.15	+.48	+.17
Clad 75SO	+.18	+.08	+.15	+.10	+.11	+.28	+.33	+.46	+.05	0.00	+.14	+.04
Clad 75ST	+.19	+.04	+.38	+.08	+.11	+.32	+.31	+.41	+.14	+.05	+.06	+.02
M-a	—.60	—.54	—.55	—.58	—.63	—.44	—.19	—.60	—.53	—.48	—.60	—.40
Fs-lh	—.59	—.52	—.54	—.55	—.58	—.42	—.12	—.60	—.45	—.44	—.58	—.36
J-lh	—.61	—.47	—.48	—.54	—.59	—.40	—.22	—.58	—.44	—.39	—.50	—.40
1025	+.52	+.52	+.67	+.60	+.39	+.45	+.82	+.91	+.64	+.50	+.46	+.36
4130	+.42	+.40	+.42	+.38	+.35	+.41	+.68	+.86	+.48	+.43	+.34	+.26
18-8 Active	+.78	+.66	+.65	+.56	+.64	+.54	+.78	+.84	+.83	+.64	+.50	+.55
18-8 Passive	+.93	+.78	+.75	+.68	+.74	+.76	+.90	+.91	+.84	+.76	+.64	+.65
Manganese Bronze	+.77	+.80	+.73	+.78	+.72	+.75	+.85	+.88	+.84	+.82	+.80	+.80

The above potentials are referred to a zinc half cell. Potentials have all been corrected for liquid junction potentials. See Table III for composition of electrolytes.

TABLE III

Composition of Natural Electrolytes Shown in Table II

	pH	Conductivity Grains/Gallon NaCl	Calcium P.P.M.	Magnesium P.P.M.	Sulphate P.P.M.	Carbonate P.P.M.	Chloride P.P.M.	Total Solids P.P.M.	Lead	Bromide	Iron	Zinc	Chromium
1/10 Normal NaCl	6.50	320	......	......	......	....	3,550	......	....	....	....	....	....
Tap water	8.15	7.5	42.0	80.0	80.3	15.60	45.0	320	....	....	....	....	....
Distilled Water	6.64	0.0	......	......	......	....	......	......	....	....	....	....	....
Lake Water	8.32	7.4	36.0	88.0	30.8	16.8	50.0	680	....	....	....	....	....
Sea Water	7.90	1,600	......	10,620	3,949	21.6	18,719	39,216	....	....	....	....	....
Rain Water	6.30	0.1	......	......	27.7	6.8	21.0	......	....	....	....	....	....
Primer Extract	6.95	6.0	32.0	......	5.0	7.2	21.3	......	....	....	....	0.46	0.61
Exhaust Condensate	4.75	22.5	34.0	......	66.0	22.8	120.7	325	61.5	106.0	7.0	....	....
			Percent P	Percent Si	Percent Al X Fe Oxides	Percent CaO	Percent S	Percent Total Soluble Salts	Percent Chloride	Percent Moisture	Percent Carbon as Carbon Dioxide		
Soil No. 1	7.68	2.7	0.23	86.84	6.49	2.24	0.38	0.028	0.06	2.95	14.0	....	....
Soil No. 2	7.57	2.2	0.21	83.58	10.85	1.64	0.48	0.08	0.03	5.02	0.85	....	....
Soil No. 3	6.95	3.0	0.32	92.32	5.06	2.68	0.52	0.14	0.04	1.02	4.70	....	....
Soil No. 4	7.15	2.0	0.34	72.20	20.24	3.48	0.92	0.31	0.09	2.95	0.55	....	....

planes would be subjected. Examination of the data shows that there is considerable variation in the solution potentials of the same metal in the different electrolytes, in some instances .5 volts or more.

Another interesting observation is that magnesium alloys tend to become more negative in exhaust condensate, while all the other alloys become more positive. It is also easy to see why zinc chromate primer protects magnesium as its extract reduces the metal's solution potential considerably.

The corrosion engineer also finds Table II useful in helping him predict which alloys can best be used in dissimilar metal contacts for various parts of the plane. After examining the data one would be reluctant to use magnesium alloys in conjunction with any of the others where exhaust condensate may be present.

Speed Creates Corrosion Problems

Planes are flying at higher speeds today than ever before. Man is ever seeking to hurtle his body faster and faster through space as though in an effort to catch up with time. As the plane's speed is increased higher pressures cause gases such as oxygen, ozone, water, nitrogen, sulphur dioxide, carbon dioxide, etc., to be forced into closer contact with the metals. This probably increases the corrosion rate by changing the equilibrium constants of the chemical film already formed on the metal under normal conditions. The temperature of the metal in the air stream also is increased until at the speed of sound it may be 130° F to 170° F depending on the ambient temperature. In general heat tends to promote corrosion.

Metals which used to be amply protected by organic coatings suffer from the fact that these finishes have not been developed to the point where they can withstand the heat, water and abrasion of high speeds, especially is this true when aircraft are flying through storm (Figures 2 and 3). Planes which ascend and descend rapidly are also subject to considerable sweating and this causes the interior surfaces to remain wet over long periods of time.

Airplanes Are Nomads of the Earth and Sky

The range of some aircraft now being designed is global. Ships of this type may take off from the frozen confines of the north and in a few hours glide majestically to a landing in the steaming jungles of South Africa, South America or some South Sea island. There the humidity is high and the plane soon becomes drenched with water. It is saturated throughout wherever the water can seep. Fungus may be rampant and consequently all materials in the ship must be fungus proof. Steaming, sweating men will maul the ship in servicing. Perhaps the air may be filled with flying salt spray. The next landing may find the ship blasted by sandstorms in some remote desert of the world. Thus corrosion engineers must develop methods of protecting the metal from all types of atmospheres.

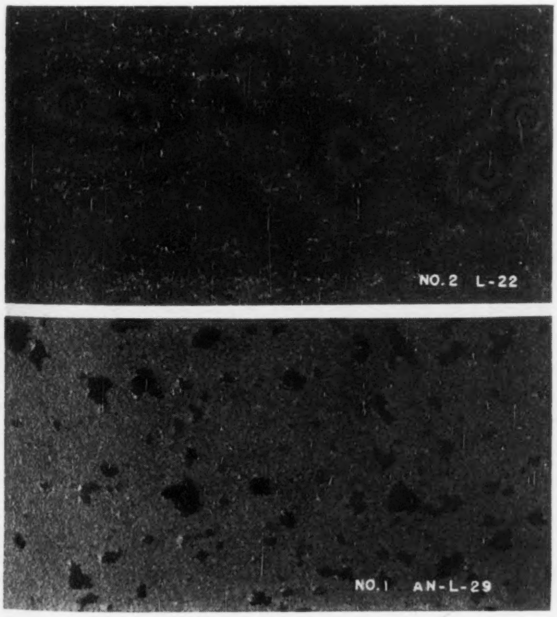

Figure 2—Effect of high speeds and rain on aircraft finishes. The aluminum specimens were treated with one dip coat of zinc chromate primer (AN-TT-P-656a, Amend. 1) each. Panel No. 1 was sprayed with one coat of cellulose nitrate (AN-L-29) lacquer containing 5 oz. aluminum paste perg allon. After drying for 24 days at room temperature, the panels were exposed to a wind and water velocity of 225 mph for a period of 50 hours in the wind chamber. (Magnification, approx. 4½×.)

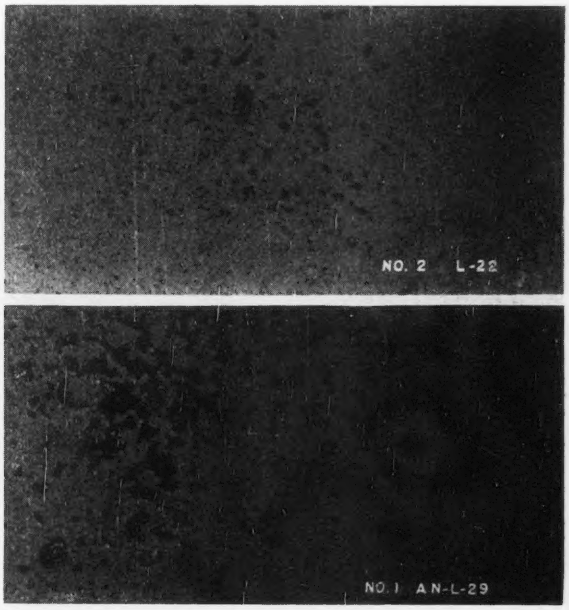

Figure 3—The aluminum panels were treated with one dip coat of zinc chromate primer (AN-TT-P-656a, Amend. 1) each. Panel No. 1 was sprayed one coat with cellulose nitrate (AN-L-29) lacquer containing 5 oz. of aluminum paste per gallon and panel No. 2 was sprayed one coat with methacrylate (L-22) lacquer containing 5 oz. of aluminum paste per gallon. After 30 days exposure to weathering on the roof of the CVAC Factory, and 5 days additional aging at room temperature the panels were exposed to a wind and water velocity of 225 mph for a period of 60 hours in the wind chamber. (Magnification, approx. 4½×.)

Cabin Pressurization Increases Worries

In order that man may fly for longer periods of time at high altitudes the cabins are pressurized. At the low temperatures encountered moisture from the breath condenses and freezes on the inside walls of the cabin. This water tends to accumulate by capillary action between lap joints and collect in low areas. As the carbon dioxide content of the air is above normal, the water has an acid reaction. This trapped water tends to break down insulation between dissimilar metals and promote corrosion through concentration cells, aeration cells and general chemical reaction on similar metals. Without water there would be no corrosion in the airplane—with it corrosion is always a good possibility.

Energy of Vibration a Potent Factor— Causes Metal Fatigue

Energy input to the metal and frequency of vibration are continuously being increased. It is known that vibrations of certain high frequency or low frequency with high energy input can cause chemical changes to take place. As the mechanism for driving the ships become more powerful and their speed is increased, vibrations of higher frequency and energy are being transmitted into the metal. Gaines[1] has proved that relatively low frequencies having sufficient power input can cause terrific heating of materials. Bergmann[2] points out that the generation of heat at the boundary surfaces of two substances transversed by ultrasonics is especially strong.

Wood and Loomis[3] describe an interesting experiment where the neck of an Erlenmeyer flask is drawn down into a rod of about .5 mm thick. The flask is then put into an oil bath of an ultrasonic generator. The high-frequency vibrations are then concentrated by the glass into the point of the flask. The point of the flask will then bore holes in wood accompanied by large quantities of smoke and sparks. It will also bore holes in glass. The glass is melted into small spheres, evidencing the intense heat produced. It is not too difficult to imagine a design in metal which would have the geometrical configuration necessary to act in the same manner as the above flask when placed in an acoustical or ultrasonic field. In like manner chemical reactions have been caused to take place by ultrasonic frequencies, N_2 to form HNO_2 and NH_3, O_2 to form H_2O_2 and many others.[2]

Marinesco[4] notes that the electromotive force of a cell changes when intense ultrasonic radiation falls on a plate forming one of the electrodes. The author believes that future designers are going to be plagued with a tendency towards failure of all types of materials from this cause (corrosion fatigue, fatigue and fretting corrosion) unless specific attention is paid to design to reduce the possible concentration of vibrational energy in the various assemblies.

Too High Altitude May Cause Metal Sickness

Man is ever trying to extend his domain. Some want to build submarines which will travel at greater depths in the ocean. Others would like to build terrestrial machines which could travel through the earth like an earth worm. Airmen want to fly higher and higher and they are vexed at the thought of being tied too close to earth. However, as machines are built which will carry them further away from the surface of the earth, the corrosion engineer again is faced with a headache. What will happen to the natural protective films that are formed on metals at the earth's surface? The oxygen and moisture content of the air decreases rapidly at high altitudes and at the lower vapor pressure of these gases and perhaps that of others the composition of the protective film will probably change. This would be especially true when ships were flying at a high rate of speed so that their surfaces would be warm.

Ships Filled With Gadgets

Not too many years ago all an airpane had to do was fly. However, since then it has literally speaking been 'taught to do tricks." It must now carry on many functions beside maintaining itself in the air. There must be multitudes of instruments for navigation, bombing, automatic pilots, etc. Armament has been added until the aircraft of today may be virtually a flying battleship. Each and every addition of equipment tends to magnify the problems of corrosion.

Non-inflammable Gases Used To Fill Empty Fuel Tanks

It is well known that gasoline or other hydrocarbons, when exposed to air, at certain temperatures will form a gas-air ratio which is explosive. During flight of aircraft when the temperature of the fuel reaches a certain limit, depending upon the altitude of the ship, an explosive mixture of air and fuel normally would be formed. However, the formation of an explosive mixture is prevented by displacing the air in the tank with an inert gas. The Russians use exhaust gas which they cool and force directly into the tank. This is an unlimited supply of supposedly inert gas, but it is so corrosive in nature that the aircraft manufacturers in this country hesitate to use it. However, exhaust gas is the most likely candidate for future purging of fuel tanks, and the corrosion engineers must figure out some way of making this possible.

At present Convair is using a novel method of purging fuel tanks. This consists of sublimating dry ice at a controlled temperature in such a manner as to supply, when needed, the proper quantity of carbon dioxide to the fuel tanks.

Electrical Systems' Voltage Being Raised

The voltage and frequency of AC electricity is constantly being raised in the aircraft. The reason is that the horsepower of a motor per given weight is increased considerably, and at the same time smaller wires can be used to transmit the power. Again, the resulting eddy currents which are induced by the high frequency, high voltage AC produce a corrosion problem in that stray currents will tend to promote anodic, and in some places, cathodic corrosion.

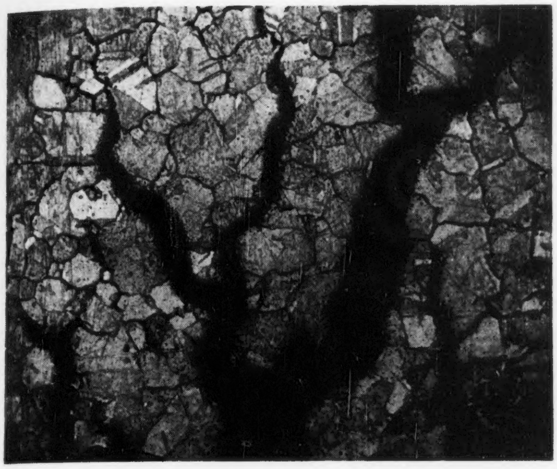

Figure 4—A micrograph of a piece of Inconel removed from an aircraft exhaust heat exchanger. This is a typical case of stress corrosion coupled with large grain growth. (Magnification about 70×.)

At the same time insulation between dissimilar metals becomes harder to hold.

Lead and Bromide Content of Fuel Poses Problem

In order to raise the octane rating of aviation fuel, it is necessary to increase the amount of tetraethyllead mixture added to each gallon. The tetraethyllead contains a scavenging agent, ethylene dibromide. The lead plus the bromide creates a difficult corrosion problem in exhaust collector rings, heat exchanger units, and any other structures which the exhaust fumes tend to contact (Figure 4). The overall corrosion resistance of the engine is likewise lowered by the heavy additions of lead and bromides to the gasoline.

Refuse Disposal a Problem

Body fluids have long been known to be highly corrosive to many metals. This is especially true of aluminum, magnesium and steel. When the refuse disposal system is such that during flight the material is dissipated into the air stream, quite frequently it comes in contact with the outer skin and seeps into faying surfaces and around rivets. Under such circumstances, unless the surface of the ship is washed immediately upon landing, there is an excellent chance of the affected metal corroding. The author has seen ships blossom out with corrosion within a few hours after having parts of its surface covered with urine from an improperly functioning disposal system. Tobacco juice is another bad actor and many an airplane skin has been ruined because someone used structural lightening holes as spittoons.

Testing Sometimes Presents Corrosion Problem

Convair builds what is called an integral fuel tank. This type of tank is formed by the structure of the wing and depends upon fuel tightness being built into each and every part. In order to test the wing tank to make certain it won't leak, air pressure is applied to the inside and a bubble fluid smeared on the outside so that leakage will be indicated by the formation of froth or bubbles. When all-aluminum alloys were employed in the wings, soap was first used for testing and then later 2 percent Nacconol NR because the soap was too corrosive. This was fine until magnesium made its appearance in dissimilar metal couplings with aluminum. Then galvanic corrosion began to show up after every testing operation. A considerable amount of work was done on this problem (Table IV) and finally a modified Nacconol solution was developed using 2 percent Nacconol, .5 percent $Na_2Cr_2O_7$ and .5 percent Carbowax 1500. The new bubble fluid had the advantage that it would form a protective coating on any bare magnesium surfaces present and would not promote galvanic corrosion.

How Convair Minimizes Corrosion On Its Planes

A. Design

The designers in conjunction with the corrosion engineers make every effort to accomplish the following:

1. Utilize metal of proper strength for each application.
2. Avoid stress concentrations by proper design of parts.
3. Provide adequate drainage of all assemblies and structures.
4. Avoid use of dissimilar metals in areas which are subject to severe corrosive conditions.
5. Avoid use of non-metallic materials, which absorb and hold water, in faying surfaces, gaskets, etc.

TABLE IV

Corrosive Effect of Various Bubble Fluids on Clad 24 ST Aluminum and Fs-1h Magnesium Alloys

SAMPLE	Surface Tension Dynes	Storage Stability	pH	Conductivity as Gr./Gal. NaCl	Dissimilar Metal Potential 24ST-Fs-1h Volts	168 Hr. Immersion Corrosion Test Weight Loss			
						24 ST Clad	Fs-1h	Dissimilar Couple	
								24 ST	Fs-1h
Ivory Soap 1%	20.0	*	10.7	50	.34	—.002	—.002	+.01	—.002
Dreft 1%	21.9	OK	9.3	225	.86	+.016	—.006	—.250	—.485
Nacconal RR 2%	29.3	OK	5.4	450	.86	.000	—.002	—.368	—.714
Nacconal 2% Sodium Dichromate 5% Carbowax 5%	29.0	OK	4.4	520	.74	+.001	—.006	+.002	—.005
Kelite Bubble Fluid 2A	....	OK	12.7	700	.12	—.105	—.004	—.065	+.003
Kelite Bubble Fluid 10	27.5	OK	7.0	700	.46	.000	—.048	—.442	—.447
2-Amino-2-Methyl-1-Propanol	†58.5	OK	11.5	28	.00	....	(No corrosion tests)		....
Liquid Soap	24.0	Fair	9.6	22	.55	+.001	+.003	+.012	—.017
Flaxoap 2%	22.7	Fair	9.5	35	.42	.0000	—.002	—.001	‡+.002
Aerosol, Grade AY 2 %	27.0	OK	4.1	80	.72	.000	—.005	—.012	—.014

* Gells within 6 hours—typical of solid soaps.
† Surface tension too high for bubble fluid, hence no corrosion tests were run.
‡ Localized pitting (Fair condition).

The finish engineer, again in conjunction with the corrosion engineer, determines the type of finish the various metals shall have. The methods used by Convair for protecting metals against corrosion are shown in Table V. It is to be noted that zinc plating is no longer used, because of the fact that Convair has found that zinc plate has poor corrosion resistance in areas of high humidity. This has also been substantiated by other research workers.

B. New Means of Joining Metals

One of the greatest contributing factors in prevention of fatigue in thin sections is a new method of joining metals together which was developed by Convair. The metals are fastened together with thermosetting adhesives. Because all areas of the lap joints are bonded there is no sharp concentration of stresses such as is encountered in riveting, bolting or spot welding. An example of the superiority of this type of construction over riveting or spot welding is shown by a fatigue test which is still in progress. Identical parts were made; one by riveting, one by spot weld and the other by Metlbond or Silabond (trade names under which cements are sold). The riveted and spot welded assemblies failed the fatigue test after 10-12,000,000 cycles. The cemented part has not yet failed after 200,000,000 cycles. Convair has never had a Metlbonded part fail in service. The cement also seals the lap joints and is excellent protection against corrosion. Developments within the past few months have lowered the cost of this type of fabrication below that of riveting.

C. Shop Troubles Prevented

The design and finish of parts may be approaching perfection, but unless the proper shop facilities and trained personnel are available all effort may be in vain. Below are listed some of the musts in the shop.

1. The shop must be kept clean (Figure 5).*
2. Air conditioning is necessary for best fabrication of parts in order to cut down perspiration and dust.
3. Rafters and other parts of shop must be kept clean and well painted, otherwise rust will filter down on to the aluminum and magnesium parts setting up corrosion.
4. All dies, etc., must be kept clean in order to prevent foreign particles being forced into the surface of the metal during the forming operation, thereby lowering corrosion resistance.
5. All processing solutions must be controlled within close limits in order to insure proper and uniform work.
6. Parts which are processed through water solutions must be thoroughly dried prior to stacking. If this is not done corrosion may occur within a few hours.
7. Magnesium parts which have had all protection removed must be given temporary protection by application of an oil such as Oakite Protective Oil.
8. Metals must be protected against scratches during fabrication. This is especially true of clad aluminum alloys (Figures 6 and 7).
9. After parts have been given their final cleaning and/or chemical finish, gloves must be worn in order to prevent contamination of their surfaces prior to painting (Figure 8).
10. Parts must be made to fit, otherwise stresses may be induced during assembly which could later cause failure by stress corrosion.

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* Figure 5 in this article is the photograph used on the cover of this issue.

TABLE V

General Finish Requirements for An Airplane

	GENERAL REQUIREMENTS				
Aluminum Alloys	**Plating, Chemical, Electro-Chem. Treat.**	**Specification**	**Organic Coating**	**Specification**	**Number of Coats**
2S, 3S, 52S, 53S, 61S, 218 Clad 17s, 24S, and 75S...	None	....	*Exterior none	....	....
Non clad 17S, 75S, 24S sheet, extrusions, tubing, bar, castings and forgings of 13, 14S, 17S, 24S, 75S, 195 195 and	Anodize	AN-QQ-A-696	All surfaces zinc chromate primer exterior aluminized lacquer	AN-TT-P-656a Amend. 1 AN-L-29	1 coat 1 coat
220 Castings	5% Chromic Acid	....	Zinc Chromate primer	AN-TT-P-656a Amend. 1	1 coat
A17S, 17S, 24S and 56S Rivets	Anodic	AN-QQ-A-696	None	....	....
Magnesium Alloys† All Magnesium Alloys	CVAC No. 1 Anodic (Manodyz)	Interior Surfaces	Zinc Chormate primer	AN-TT-P-656a Amend. 1	1 dip coat 1 spray coat
		Exterior Surfaces	Zinc Chromate primer Aluminized lacquer	AN-TT-P-656a Amend. 1 AN-L-29	1 dip coat 1 spray coat
Steel Corrosion Resistant Steel (18-8)	Passivate	....	*	....	....
1025, X4130, X4340, etc., Non corrosion resistant	Cadmium	AN-P-61	Zinc Chromate primer	AN-TT-P-656a Amend. 1	1 coat
Steel cables (Specs. AN-RR-C-43, AN-RR-C-48, AN-C-76)	None	....	Rust Preventive Compound	AN-C-52, Type 1	1 dip coat
Dissimilar Materials All dissimilar metal contacts	As specified for each part involved	....	Zinc Chromate primer	AN-TT-P-656a Amend. 1	1 coat min. on each faying surface.
Cadmium plated bolts, nuts, washers, screws, rivets and press fit bushings used with magnesium	....	....	Unthinned zinc chromate primer or equivalent	AN-TT-P-656a Amend. 1	Inserted with wet coat

* All interior surfaces are given one spray coat of zinc chromate primer with exception of fluid and gas lines, interiors of fuel and oil tanks.

† A fraction of one percent of magnesium parts receive other coatings. Over exterior surfaces of anodized magnesium alloys there is applied one dip coat of zinc chromate primer and one spray coat of aluminized lacquer. Recently the practice of spraying an approximately .05 mil coating of zinc chromate primer over aged dip primer coat has been initiated. The only reason for this is to reactivate the aged primer so the aluminized lacquer will not peel off.

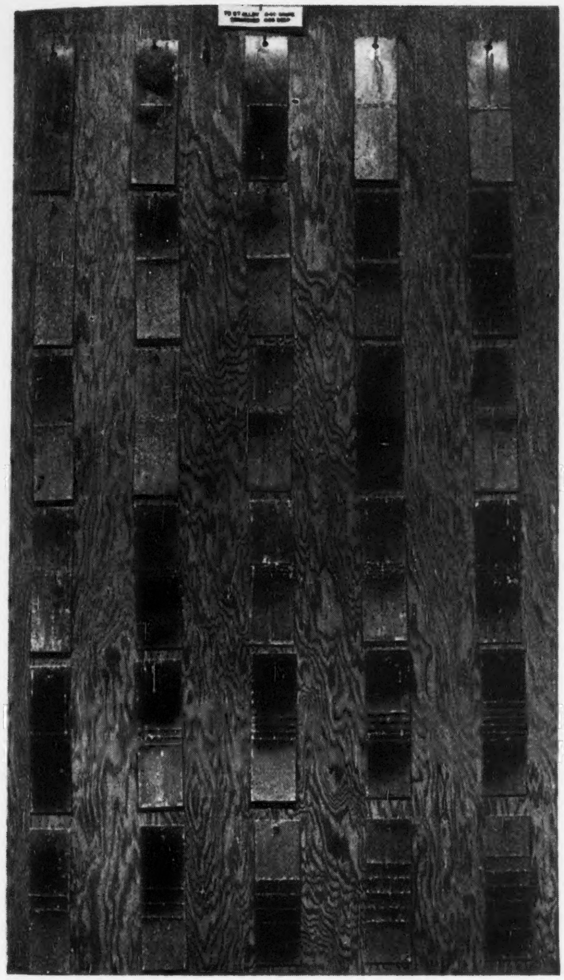

Figure 6—Showing corrosion on scratched clad 75ST. The specimens were exposed to a salt spray corrosion test (AN-QQ-S-91) for 310 hours after which the tensile strength was determined and compared to controls (both scratched and unscratched). See Figure 7.

Figure 8—Handling cleaned parts with gloves. All anodized material must be handled with gloves prior to sealing with zinc chromate primer. This is also true of many other processes.

The author does not wish to imply that the above mentioned procedures for prevention of corrosion are perfect. What is really meant is that the procedures outlined are equivalent at least to the best known to date, and that only hard work on every one's part can bring about that ultimate goal of all corrosion engineers—Complete Protection of Metals in All Environments.

Acknowledgment

The author extends his appreciation to the following: K. E. Dorcas, who conducted most of the test work and compiled a large amount of the data; S. Witkoff and Miss C. F. Gilley for proof reading of manuscript and Mrs. G. E. Geyer for typing and many helpful suggestions.

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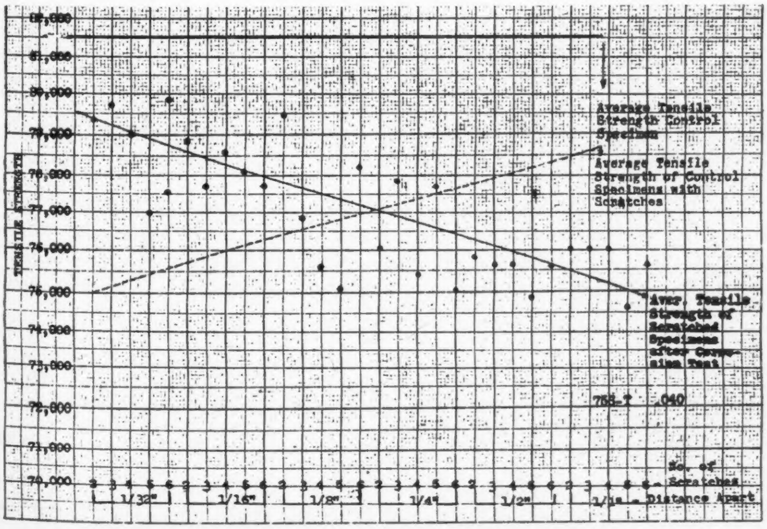

Figure 7—Effect of corrosion on tensile strength of scratched clad 75ST. The data plotted in this graph were obtained from specimens shown in Figure 6. It is interesting to note that the further apart the scratches are spaced the more effect corrosion has on tensile strength. This is just the reverse of scratch effect prior to corrosion. In the above test the tensile load was always applied perpendicularly to the scratches.

The Use of Ammonia in Control Of Vapor Zone Corrosion of Storage Tanks

By F. T. GARDNER, A. T. CLOTHIER* and F. CORYELL***

Abstract

Laboratory studies have shown that ammonia in concentrations as low as 0.4 percent in systems containing 2 percent hydrogen sulfide by volume is effective in controlling vapor zone corrosion.*** Results of experimental field work with 55,000-barrel tanks showed that the efficiency of protection gradually increased from 16 percent when an inhibitor injection rate of 1.4 pounds per tank per day was employed to almost complete protection when 12 to 15 pounds per day were added to the tank vapor zone. The uninhibited corrosion rate measured simultaneously in tanks in similar service averaged 273 mdd, or 0.053 ipy, for the entire test period.

The Interstate Oil Pipe Line Company is now using ammonia in treating eight tanks at three pipe line stations. Three tanks at Magnolia Station in southern Arkansas and two at Moore Station in northern Louisiana are receiving ammonia from bulk storage. The three remaining tanks under treatment are at the Yellowstone Station near Billings, Montana. Ammonia usage is economical and is equally effective in both areas despite the great differences in climatic conditions.

Introduction

THE RAPID INCREASE in the volume of hydrogen sulfide-bearing crude oils being produced within the past ten years has served to emphasize the extent of the severe form of corrosion attack which occurs in the vapor areas of tanks handling these oils. The results of several years' experience in the use of ammonia for the prevention of this type of corrosion are presented in this article. Laboratory phases of the work were performed at the research laboratories of The Carter Oil Company, Tulsa, Oklahoma. Field studies were carried out in Carter lease tanks and at various stations of the Interstate Oil Pipe Line Company, Tulsa, Oklahoma.

History and Extent of Problem

The first report of a high rate of hydrogen sulfide corrosion in the vapor zone of steel tanks handling sour crude oils to be found in the technical literature is dated 1925.[1] It seems highly probable that this type of corrosion may have been observed in a few areas, such as eastern Kentucky for example, at an even earlier date, but reports of this have not been found in the literature. The extent and significance of the problem were called to the attention of the petroleum industry by numerous writers during the period 1926-28.[2, 3, 4, 5, 6, 7, 8]

The domestic production of sour crude oil has risen during the past 25 years from a few thousand barrels per day to something well upward of 1,000,000 barrels per day. Unfortunately, separate statistics for sour and sweet crudes are not maintained by the industry so that the precise amount of sour crudes in storage and transit is not a matter of record. (The term "sour crude" as used in this report will, in all cases, denote crude oil containing dissolved hydrogen sulfide while "sweet crude" is that which is substantially free of hydrogen sulfide.) The notable domestic sour crude producing areas include West Texas, Central Kansas, Southwest Arkansas, and certain horizons in Illinois, Kentucky, Michigan, Montana and Wyoming.

The effect of sour crude has been extended further by the practice of blending sour and sweet stocks. The result of this increase in the amount of sour stocks produced and transported has been a consequent rapid increase in the amount of tankage subjected to severe corrosive conditions. Many operators have been forced to convert from sweet to sour crude service during the past decade with the result that tankage which has been used for handling sweet crude for many years with inappreciable corrosion has shown the severe damages of vapor zone corrosion after only a few years in sour crude service.

Tank impairment due to this type of corrosion attack has become an important factor in pipe line economics. It is difficult to place a monetary estimate on the magnitude of this expense to the American petroleum industry, but a conservative estimate would be $1,500,000 per year. The annual cost of vapor zone corrosion is probably declining at the present time, as a result of application of remedial measures.

★ A paper presented at the South Central Regional meeting of the National Association of Corrosion Engineers, Dallas, Texas, October 3-4, 1949 and at the American Petroleum Institute meeting in Chicago, Ill., November 7-10, 1949. Previously published in whole or part in *Oil and Gas J.*, **48**, No. 27, 238-246 (1949) Nov. 10 and *Petro. Eng.*, **XXI**, No. 12, D 18-20 (1949) Nov.

* The Carter Oil Company Research Laboratory, Tulsa, Okla.

** Interstate Oil Pipe Line Company, Tulsa, Okla.

*** Patent applications have been filed to cover this development, and patent rights have been assigned to Standard Oil Development Company at Elizabeth, N. J.

Mechanism of Vapor Zone Corrosion

It is well established that a rapid rate of corrosion in the vapor zone of steel storage tanks is dependent upon the simultaneous presence of an aqueous phase (droplets of condensed moisture), hydrogen sulfide, and oxygen.[9, 10]

A probable mechanism for the rapid corrosion process involves the following steps:

1. Condensation of drops of moisture on the surface of the tank metal.
2. Solution of H_2S and oxygen in the condensed moisture.
3. Partial oxidation of H_2S to S and other oxidation products.
4. Establishment of local corrosion cells over areas in contact with the condensed droplets, initially having an iron carbide (or other surface heterogeneity) cathode and an iron anode, and ultimately having an FeS cathode and an iron anode.

Vapor zone corrosion frequently has been reported as most severe on the north (cool) side of tanks where condensed moisture would be expected to exist for a greater portion of the time than on the other sections of the tank. Free sulfur and sulfate ion have been found in condensed moisture droplets exposed to hydrogen sulfide and oxygen in both field and laboratory tests. The pH of condensed moisture droplets exposed to atmospheres containing oxygen and hydrogen sulfide has been found to be approximately 3 on a stainless steel surface where the anode in the local cell is passivated to a marked degree. On an ordinary unpassivated steel surface, where rapid consumption of hydrogen ion occurs in the local corrosion cell, the corresponding pH has been found to be approximately 5-6. These facts are in accord with the corrosion mechanism postulated.

Use of Ammonia as a Vapor Zone Corrosion Inhibitor

Laboratory Results

In the first qualitative work conducted at the Carter Research Laboratory with ammonia as a possible inhibitor of vapor zone corrosion ammonium carbonate was utilized as the source material. A steel coupon exposed for a period of one week in a corrosive atmosphere containing hydrogen sulfide suffered extensive corrosion. A second coupon exposed under like conditions, with the exception that ammonium carbonate was present in the vessel, was bright and uncorroded.

In the subsequent laboratory study of the vapor zone corrosion problem, it was necessary to develop both techniques and equipment for obtaining reliable corrosion rate measurements. It was found that reproducible corrosion rates could be obtained only when the test coupon was exposed to changes in temperature which would cause moisture to condense upon it.

A suitable corrosion test cell shown in Figure 1 was devised for simulating field corrosion conditions on a laboratory scale. It consists of a ½-gallon widemouth glass jar for which the closure is formed by the corrosion test coupon. The accurately-weighed, sandblasted steel specimen has two holes equipped with one-hole neoprene stoppers through which a corrosive gas blend similar to that found in crude oil storage tanks can be introduced. A neoprene gasket between the panel and the top of the jar assures an air-tight seal when the panel is held in place with the usual ring-type closure. Sufficient water is placed in the jar at the start of the test to assure that the vapor area will be saturated throughout the test period. Exposure of the cell to the daily temperature cycle outside the laboratory results in condensation of moisture on the panel during the cool period of the day in the same manner as occurs in field tankage. Reliable corrosion rate measurements can be made in 24 hours and uninhibited corrosion rates are about equal to those observed in the field.

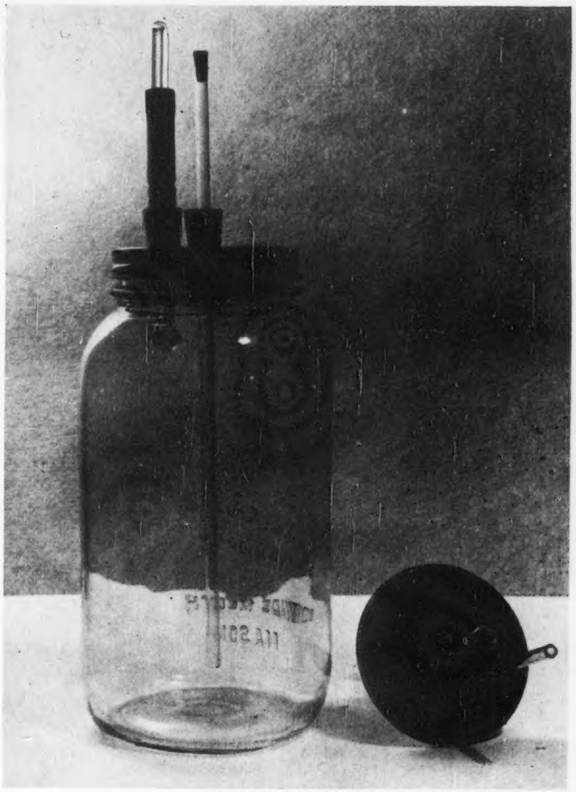

Figure 1—Corrosion test cell.

Carefully controlled tests made in the vapor zone test cell with 2 percent hydrogen sulfide present showed that corrosion was controlled by a concentration of NH_3 equal to only 0.4 percent by volume, although 4 percent of this base would have been necessary for neutralization, according to the equation $2NH_3 + H_2S \rightarrow (NH_4)_2S$. It is a well established procedure in refinery practice to control hydrogen sulfide corrosion in high temperature equipment by addition of ammonia or other bases in quantities sufficient to neutralize the acidic gases, but it will be noted in this case that the amount of ammonia used was only one-tenth that which would be required for complete neutralization of the available hydrogen sulfide. The protection afforded is believed to be due to the buffering action of ammonium salts formed by reaction with acidic materials dissolved in moisture droplets on the steel surface of tanks rather than to general neutralization.

Field Results

Tests in Lease Tanks

An extended field test in which ammonium carbonate was used as a source of ammonia was carried on continuously for a two-year period in four 300 and two 500-barrel lease tanks in the Magnolia Field in southern Arkansas. The work completed showed that an appreciable overall reduction in corrosion losses was achieved and that the use of ammonia for controlling corrosion in large storage tanks appeared feasible and practical. The cost of chemical required for treatment of small lease tanks was about $25 per tank per year. It is felt that the method of placing ammonium carbonate in containers located in the vapor zone is satisfactory for protection of isolated small capacity tanks.

Anhydrous Ammonia Tests

Because it was apparent that ammonium carbonate, a bulky, solid material, could not be used as a practical source of ammonia for the treatment of large capacity tanks, the use of anhydrous ammonia was considered the most logical means of introducing the inhibitor into the vapor zones in the desired quantities.

Prior to initiation of a test of the effectiveness of anhydrous ammonia in protection of large pipe line tanks it was necessary to develop a method for determining the corrosion rate occurring in the tankage to be used. The method of exposure of panels shown in Figures 2 and 3 was found to be quite satisfactory. Sections of 16-gauge tank steel which were prepared by sandblasting, coding with numbers, weighing, and coating on one side with one of the commercially available vinyl coatings were bolted over windows cut in manhole covers, using a gasket to keep leakage to a minimum. It has been found subsequently that single panel installations made on thief hatch covers are satisfactory for making measurements in tanks not equipped with manholes. Corrosion rates observed employing this type of exposure have been of the order of 30 times as great as those observed with panels hanging inside the tank. Since the panel is an integral part of the tank roof, it is believed that it reflects the true rate of attack on the roof metal. Also the rates measured are of the same magnitude as the rates calculated from the service life of tankage.

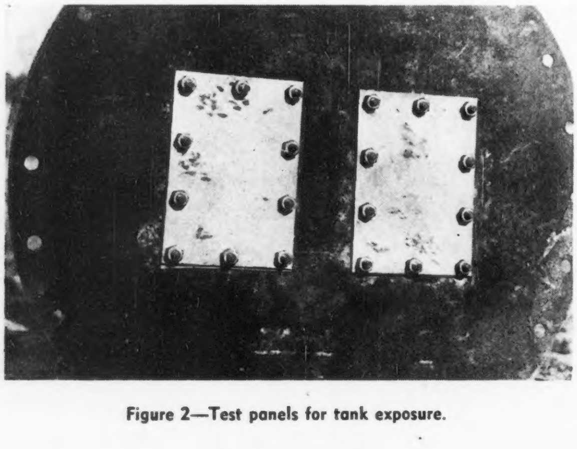

Figure 2—Test panels for tank exposure.

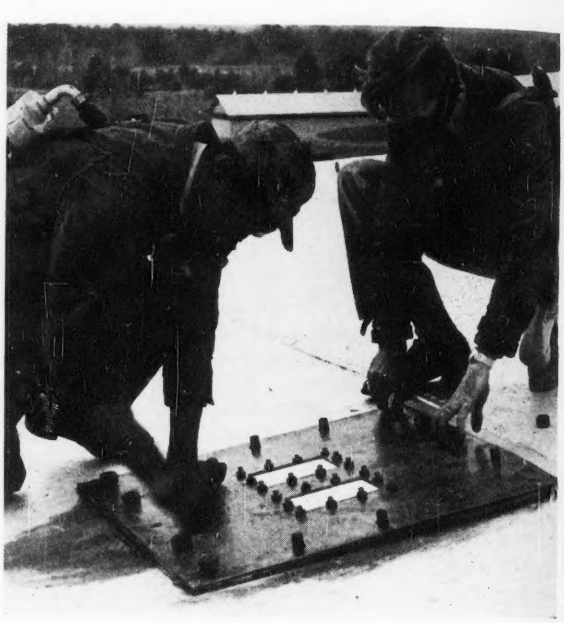

Figure 3—Attaching test panel to tank roof.

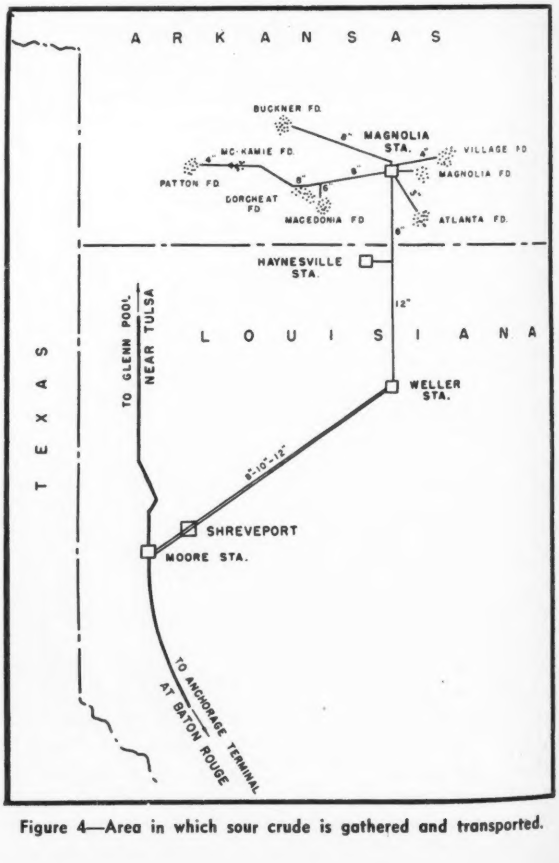

Figure 4—Area in which sour crude is gathered and transported.

In the course of observation of uninhibited corrosion rates in several tanks it was found that many factors have an effect on the severity of attack. These include the season of the year, general climatic conditions, the frequency of use of the tank, tightness of the tank roof, and the type of crude handled. The hydrogen sulfide content of the crude is not a critical factor since relatively small concentrations of hydrogen sulfide will cause severe corrosion in the presence of oxygen.

Experimental field use of anhydrous ammonia was initiated in Interstate tanks in the South Arkansas-North Louisiana area. The anhydrous ammonia used in experimental work was obtained in 150-pound cylinders at a cost of 18½ cents per pound. Treatment was accomplished by bleeding ammonia from the cylinder on the ground into the center of the tank roof by means of a rubber hose. The amount of ammonia injected was determined by the reduction in weight of the cylinder and contents, which were mounted on platform scales for convenience. Effectiveness of the treatment was determined by compar-

TABLE I

Results of Experimental Treatment of 55,000-Barrel Sour Crude Storage Tanks With Anhydrous Ammonia

Tank and Location	Exposure Dates	Treatment Lb. NH_3/Day	Corrosion Rate Mdd	Control Corrosion Rate* Mdd	Percent Retardation
A (Magnolia)	2/26– 6/12	1.4	111	132.5	16.2
A (Magnolia)	6/12– 9/5	3	136	206†	34.0
B (Weller)	7/17–9/8	5	95	206†	54.3
A (Magnolia)	9/8 –10/7	8	83	280	70.3
A (Magnolia)	10/7 –11/11	8	60	290	79.3
B (Weller)	9/8 –10/11	10	51	280	81.7
B (Weller)	10/29–11/12	10	2.9	290	99
A (Magnolia)	12/10– 1/13	10	0	220	100
A (Magnolia)	11/11–12/10	12	7.2	400	98.2
B (Weller)	11/12–12/10	15	4.3	400	98.8

* Control corrosion rates are derived from the average panel weight losses of five untreated tanks with the exception of the first test listed for which Tank B, then untreated, served as a control.

† Control rate data are not available for this test period and the figure 206 represents an average of rates measured just prior and subsequent to the test in question.

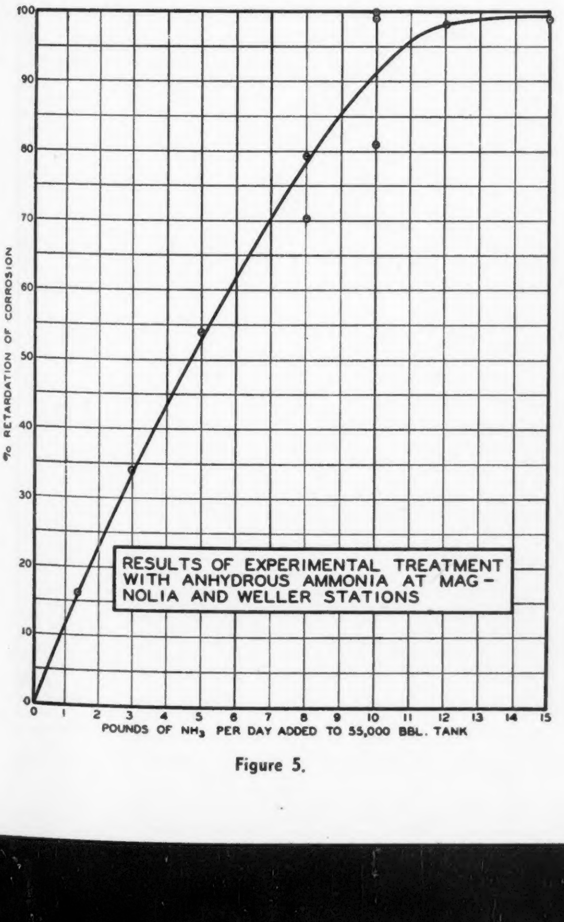

Figure 5.

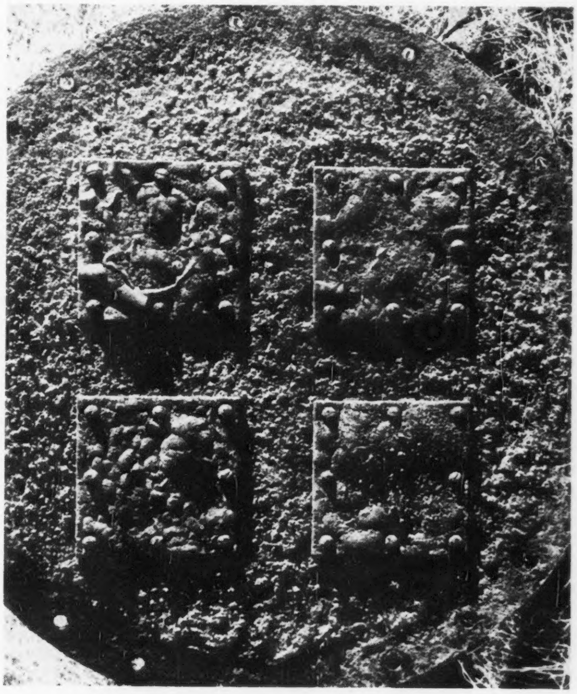

Figure 6—Panel removed from untreated tank.

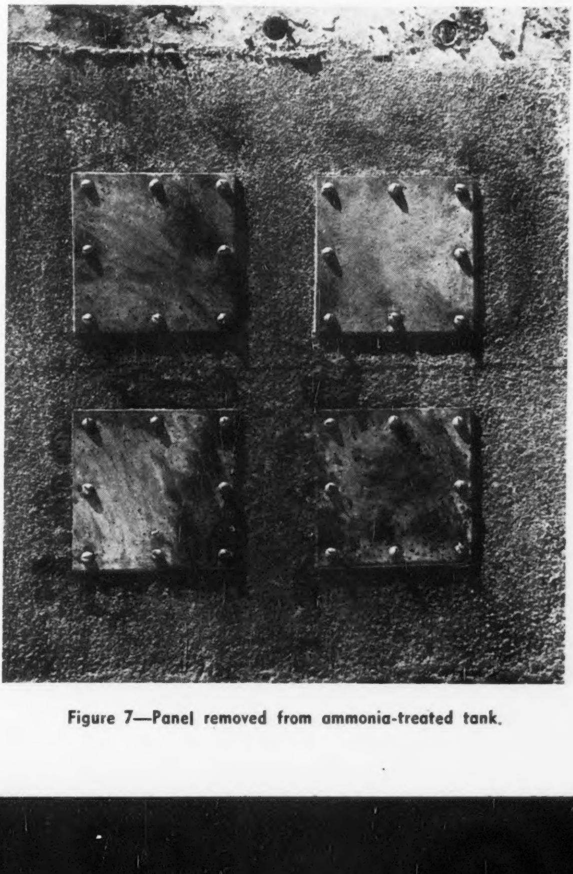

Figure 7—Panel removed from ammonia-treated tank.

ison of panel weight losses measured simultaneously in treated and untreated tanks in the same area.

During the experimental phase of the work a total of seven tanks located at Magnolia and Weller stations was utilized. Figure 4 is a map of the Interstate system in this area. Of two tanks at Magnolia one was treated with ammonia and one served as a control, while at Weller one tank was treated and four were used as controls. All of these tanks are in service in an area where severe corrosion has been observed and in addition are working tanks which have regular operating cycles. The tanks at Magnolia Station are used for the accummulation of crude from the fields for "batching" the 33 miles to Weller Station where the oil is set out before being pumped to Moore Station at Shreveport.

In order to secure complete data on the use of anhydrous ammonia in 55,000-barrel tanks, an initial low concentration of treating chemical was used which was increased in steps until the desired protection level was attained. The experimental work continued for 14 months during which time control corrosion rates ranged from 132.5 mdd to 400 mdd (milligrams per square decimeter per day; one inch per year is equivalent to about 5100 mdd) making it necessary to report results as percentage retardation instead of in absolute corrosion rate values. The weighted average control corrosion rate was 273 mdd for the test period. This is equivalent, on a 55,000-barrel tank, to a metal loss of 59 pounds per day or 10.6 tons per year. At this rate the entire tank roof would be consumed by corrosion in about four years which checks rather well with the known service life in the Magnolia area. Results of the field tests are tabulated in Table I and are shown graphically in Figure 5.

The significant fact noted in this table is the increase in the percentage of retardation accompanying the increase in the amount of ammonia added per day. The data presented also show that weight losses are more pronounced in the winter months when moisture remains on the interior tank surface longer each day.

The effect of ammonia treatment is shown clearly in Figure 6 which shows a set of panels removed from one of the control tanks after 28 days' exposure and Figure 7, which shows a similar set exposed simultaneously in a tank treated with 15 pounds of anhydrous ammonia per day. Figures 8 and 9 show one panel from untreated and treated installations, respectively, after descaling in the laboratory.

Field Application Of Ammonia Treatment

As a result of the successful completion of the experimental work with ammonia, the decision was made by Interstate to establish a permanent installation for ammonia injection at Magnolia Station for the protection of three tanks in sour service. Bulk ammonia tanks were found to be commercially available in sizes of 110, 500 and 1000-gallon capacity. To reduce the frequency of han-

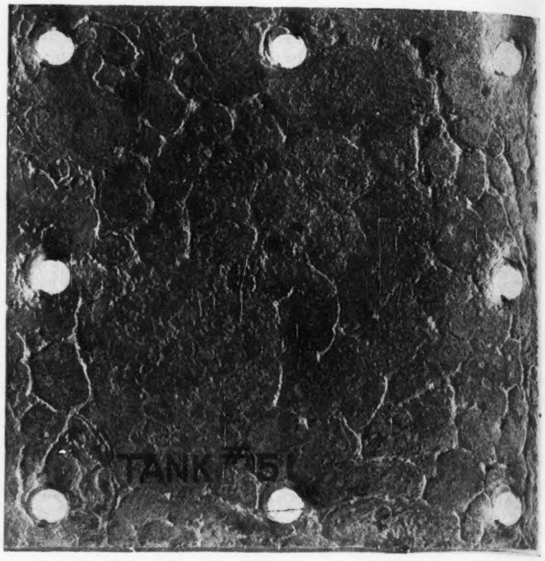

Figure 8—Descaled panel from untreated tank.

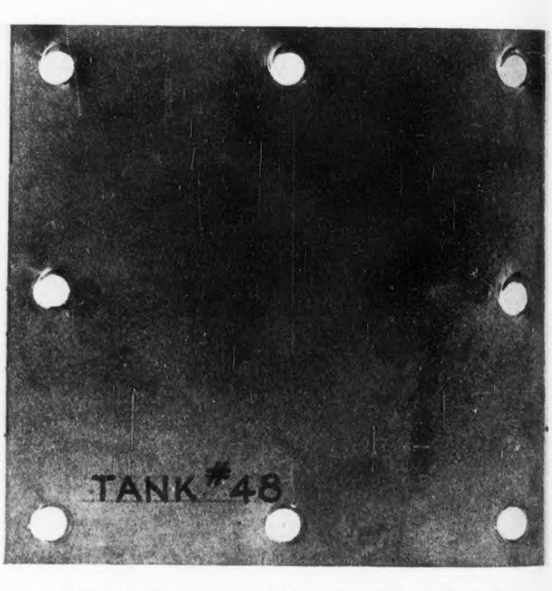

Figure 9—Descaled panel from ammonia-treated tank.

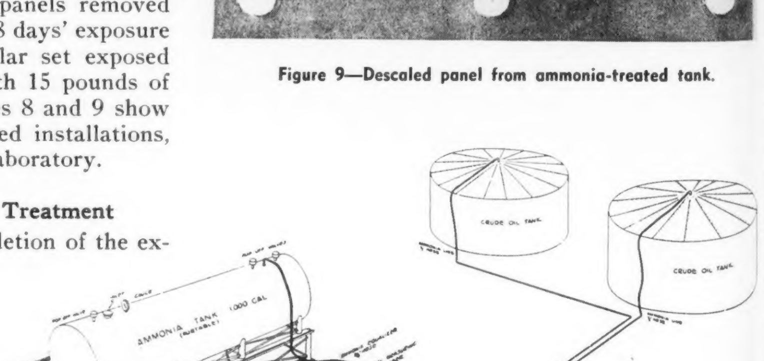
CRUDE OIL TANK
CRUDE OIL TANK
AMMONIA TANK (PORTABLE) 1000 GAL
GAUGE
GAUGE
AMMONIA INJECTION INSTALLATION
ARKANSAS – LOUISIANA

Figure 10—Ammonia injection installation Arkansas-Louisiana.

dling, a 1000-gallon tank was purchased. A diagrammatic sketch of the tank and dispensing equipment is shown in Figure 10. A single measuring chamber equipped with a sight glass is used to determine by volume the amount of ammonia used in treatment. The liquid ammonia is expelled from this chamber into the expansion tank where it vaporizes and travels through a ¾-inch black iron pipe directly to the storage tank being treated. Galvanized pipe should not be used. In this apparatus an expansion chamber is provided for each tank to be treated. The cost of the installation was under $2000. However, for average conditions a setup similar to this would require an investment of about $1700 for the first storage tank to be treated and $100 for each additional tank. The 1000-gallon ammonia tank is mounted on skids so that it can be loaded on a truck for transportation to a bulk plant. At Shreveport the ammonia is available in quantity at a cost of 8½ cents per pound.

In normal operations at Magnolia treatment with 15 pounds of ammonia is made daily as each tank begins to cool off and draw in air. The time required for treatment does not exceed 15 minutes daily for the three tanks, although it may take from 10 to 30 minutes or more for complete vaporization of the ammonia in the expansion chambers depending on atmospheric conditions. No additional station labor is required for operating the ammonia injection system.

Since routine treatment with ammonia was started at Magnolia Station, with the exception of a short period at the start during which it is felt that proper distribution of the treating chemical was not obtained because of the method of injection, the inhibited corrosion rate has ranged from 3 mdd to a high of only 45 mdd in Tank A. The results obtained in this tank are given in Table II. The only measurements which have been made of the other two tanks undergoing ammonia treatment show corrosion rates of only 7.9 mdd in one and 14.2 mdd in the other. Currently the degree of protection in all three tanks is ranging from 90 to 99 percent.

An injection system, similar to that at Magnolia Station, recently was installed at Moore Station near Shreveport, Louisiana. This installation, which was located initially at nearby Ida Station, was moved to Moore with a loss of only $30 worth of piping. Here two 37,500-barrel tanks are being treated with 10 pounds of anhydrous ammonia per day. Corrosion rates measured in these tanks prior to treatment averaged 150 mdd. This was cut to an average of 37.5 mdd for a reduction of 75 percent during the first 36 days after treatment. Subsequent corrosion rate measurements have shown that protection is now ranging from 95 to 99 percent complete.

TABLE II

Results of Anhydrous Ammonia Treatment of 55,000-Barrel Sour Crude Storage Tank

DATE	Exposure Time, Days	Injection Rate, Lbs./Day	Corrosion Rate, Mdd	Percent* Retardation
Oct.-Dec.	57	15	45	85
Dec.-Feb.	62	15	Not determined weights lost	
Feb.-Mar.	30	15	30	90
Mar.-April	28	15	3	99
April-May	31	15	11	96
May-June	32	15	7	96

* Referred to yearly average corrosion rate of 289 mdd determined in this area prior to the start of routine inhibitor treatment.

Severe internal corrosion of storage tanks in the Interstate Oil Pipe Line system is not limited to the South Arkansas-North Louisiana area but is also encountered at the Yellowstone Station near Billings, Montana, where three 55,000-barrel cone roof tanks have shown evidence of rapid corrosive attack. Treatment of these tanks has been started.

A diagrammatic sketch of the ammonia injection apparatus used in Yellowstone Station is shown in Figure 11. At Yellowstone, ammonia can be obtained only in 150-pound cylinders which makes necessary some variations from the bulk system installed at Magnolia. The operating principle is the same but it will be noted that in this system a volumetric measuring container calibrated in pounds of ammonia is provided for each tank and the expansion chambers have been eliminated. Treatment is applied at times

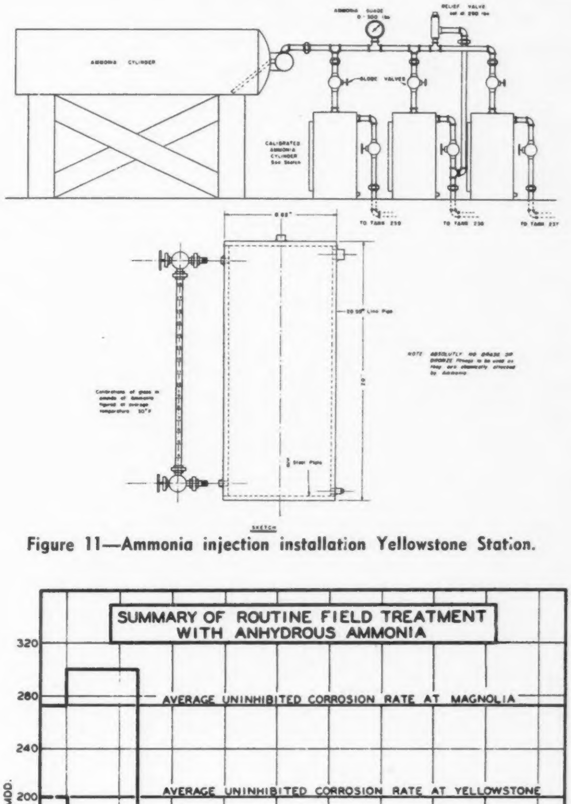

Figure 11—Ammonia injection installation Yellowstone Station.

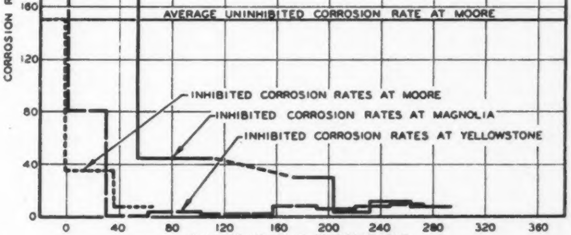

Figure 12.

when the temperature is on the way down or when tanks are being pumped out. The cost of ammonia at Yellowstone has varied from 20 to 22 cents per pound which is about 2½ times that paid at Shreveport.

Because all of the early field experience was gained in the Southern Arkansas-Northern Louisiana area where climatic conditions are totally different it was felt to be desirable to arrive at the optimum level of treatment by experimenting first with low injection rates and increasing by steps until satisfactory inhibition was effected. Table III shows the results of treatment at Yellowstone Station.

The variation in the uninhibited rate which will be noted from the table reflects the manner in which the various tanks are worked, the condition of the tank roofs and other factors. Climatic conditions prevailing in Southern Montana appear to have allowed a decrease in chemical requirement for protection to only a third of that found to be necessary in the Arkansas area.

The complete results of the treatment at the three locations described are presented in Figure 12. It should be noted in all cases that there is a strong indication that ammonia treatment does not become completely effective for about 30 days. Treatment is now proceeding in a routine manner and no further problems are anticipated in the use of ammonia as an inhibitor.

Economics

The use of ammonia normally can be justified as providing adequate protection against hydrogen sulfide corrosion at a cost lower than protective coatings. For a 55,000-barrel cone roof tank, ammonia used at the rate of 12 pounds per day and costing 8½ cents per pound, would cost $372.30 per year. An ammonia storage tank and piping facilities with an expected service life of 15 years can be installed for about $600 per crude oil tank protected. The depreciation rate would be $40.00 per year for equipment. The total material cost will therefore be $412.30 per year. In locations where only 4 pounds of ammonia per day are required, the annual cost of ammonia and attendant facilities would be $164.10 per year. These figures may be compared to the cost of a new roof and replacement of some structural members at a cost of about $17,000. In many areas, including those that require only 4 pounds of ammonia daily, an unprotected roof will become unsafe in four years. Since a roof in sweet crude service may be expected to last 20 years, the cost is $850 per year compared with $4250 per year when H_2S bearing oil is stored in the tank. Thus the corrosion cost of $3400 per tank year can be saved by the annual expenditure of $412.30, for a net saving of $2987.70 per tank year or 88 percent of the cost of uncontrolled corrosion.

TABLE III

Results of Anhydrous Ammonia Treatment of Tankage at Yellowstone Station

DATE	Exposure Time, Days	Injection Rate, Lbs./Day	CORROSION RATE, Mdd		
			Tank 235	Tank 236	Tank 237
April-Aug.	144	None	105	219	285
September	30	5	109	13	130
October	32	7	1	1	2
November	40	8	1	1	2
Dec.-Jan.	55	7*	5	8	5
February	34	8*	13	8	5
March	29	8*	7	2	10
April	27	10*	0	9	16
May	26	10*	3	10	14

* Ammonia injected every other day.

In weighing the merits of anhydrous ammonia vs. protective coatings or other means of protection the user must consider the question of a heavy capital expenditure made in one year against a small maintenance budget over a period of years. Once a tank is protected by a coating, the money is spent. If the crude stream changes from sour to sweet, there is no refund on the investment. Using ammonia, protection is applied only as long as needed. There is no time loss in tank storage use and the results obtained lie within the control of the user.

Conclusions

Vapor zone corrosion occurring in steel storage tanks which handle crude oils containing dissolved hydrogen sulfide can be adequately controlled by the use of anhydrous ammonia. Ammonia treatment is effective under a variety of climatic as well as operating conditions.

In a typical installation, the use of ammonia will result in a saving of over 88 percent of the cost of uncontrolled corrosion and will compare favorably with the cost of other means of protection investigated. Equipment and installation costs for this treatment are very moderate, and the operation and maintenance of the required equipment are simple. There is no interference with normal operating procedures or schedules.

ACKNOWLEDGMENT

The authors acknowledge with appreciation the permission of their respective companies to publish this material.

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DISCUSSION

Remarks by D. A. Shock, Senior Research Chemist, Production Laboratory, Continental Oil Company, Development & Research Dept.

The authors are to be congratulated on this timely presentation of their investigations on the use of ammonia for combating sour crude vapor space corrosion. Their data on field results, covering a number of installations in different climatic conditions showing the efficiency and economic of the use of ammonia treatment, will be undoubtedly of significant importance. It is felt that, due to the importance of possible application, a further discussion of the mechanism of the protective action would be in order.

The use of ammonia in less than stoichiometric amounts to neutralize the hydrogen sulfide present in the gas over a steel surface receiving protection is not new. This point has been recognized in refinery practice for a considerable time. Egloff and Morrell[1] in 1926 reported that the use of neutralizing agents such as ammonia for vapor space corrosion control requires only a small percentage of the amount of material required for complete reaction with the hydrogen sulfide in the gas. This has been attributed to the fact that the corrosion takes place in the liquid water film on the steel surface and the corrodent concentration will be that concentration which exists in this liquid water film. Thus the factors which influence the solubility in water of the particular gases involved will control the relative concentration in the water film.

In the case of vapor space corrosion in storage tanks, it is clearly recognized that corrosion takes place in a water film on the surface of the steel. The solubility of hydrogen sulfide where the partial pressures in the gas are less than one atmosphere follows Henry's Law, $p = Hx$ where p is partial pressure, H a constant for a specific temperature, and x the mol fraction of gas in water. On the other hand, the solubility of ammonia gas does not follow Henry's Law due to its combination with water. As a result, its solubility is considerably higher at a given partial pressure than hydrogen sulfide solubility. For illustration purposes, using gas concentration data in the paper and solubility data in the literature, the concentration of 2% hydrogen sulfide gas at 25°C calculates to be 6.9×10^{-5} weights/100 weight, whereas the protective ammonia concentration of 0.4% at 25° would give .45 weights/100 weight. It is easy to see, on this basis, that a considerable excess of ammonia probably can exist in the liquid water film over the amount required to neutralize even though the amount in the overlaying gas is much less.

While such a large excess of ammonia in the water film probably does not exist due to other compound formation, there is little doubt that a small amount of ammonia gas can be more than enough to neutralize the effect of considerable percentages of hydrogen sulfide gas overlaying a water layer. This can be demonstrated by bubbling the gas containing both hydrogen sulfide and ammonia through water containing an indicator. An equilibrium pH is reached when the water becomes saturated with the amount of ammonia and hydrogen sulfide extractable from the gas mixture. These pH values show that the relatively small amounts of ammonia will more than neutralize the high concentration hydrogen sulfide content of the gas.

This raise in pH can be expected to mitigate not only the attack resulting from solution of the acid gases but also reduce oxygen corrosion by means of limiting the solubility of the iron hydroxide. Reduction of oxygen corrosion rates by keeping the medium alkaline is also well recognized as a means of protection. Other mechanisms of protection may exist, but it is felt that, until more intensive investigation proves otherwise, the protection afforded must come from raising the pH in the droplets of condensed water on the surface of the steel. This is accomplished by a relatively small concentration of ammonia due to the fact that it is considerably more soluble in water than hydrogen sulfide.

[1] "Corrosion of Pressure Still Equipment," G. Egloff and J. C. Morrell, AIME Petroleum Development and Technology, 1926, 571-579; also paper presented AIME meeting, October 28-29, 1926, Tulsa, Oklahoma.

DISCUSSIONS ARE INVITED

Readers who wish to submit written information additive to articles published in Corrosion, or who wish to register differences of opinion with respect to any articles are urged to send such discussions to Dr. F. N. Alquist, Chairman, NACE Editorial Review Committee, Organic Research Laboratories, 20A Building, Dow Chemical Co., Midland, Mich. Doctor Alquist will submit such discussions to a member of the review committee, and after review and approval the discussion will be published.

The expression of opinions about or the addition of information to that contained in technical articles will advance the interests of NACE and make Corrosion more valuable to the membership.

Electrolysis Experiences on 115 KV High Pressure Oil Filled Pipe Type Cable Installation in New Orleans★

By *SIDNEY E. TROUARD**

Abstract

Subject discussed is a 6⅝-inch coated steel pipe line, electrically continuous throughout its 11 mile length, housing a 3-phase 115 kv, 80,000 kva power circuit. The conductors are 600 Mcm, paper insulated and operate in a special oil in the pipe line, the oil being compressed to 200 psi. The electrolysis problems encountered were unique in that the line traversed several strong stray railway current areas, necessitating heavy railway drainage near the substations. Because of the electrical continuity of the pipe line (considered necessary for personal safety on this high voltage line) and its low linear resistance, this drainage caused the pipe line to become highly negative to other metallic substructures in areas far removed from the railway substations, necessitating resistance bonding to the structures. Complicating factors were high values of AC power fault current which would tend to return to the generators over the pipe line rather than through the earth, changes in the street railway system and railway loads, a tie to a 115 kv overhead circuit vulnerable to lightning near a high voltage substation and general solid grounding necessary for protection of personnel under power fault conditions.

General

THIS PAPER describes electrolysis experiences on an 11-mile length of underground 115 kv high pressure, oil-filled, pipe type cable, laid 1946-47, through Metropolitan New Orleans. The route of the pipe cable is shown in heavy lines on Figure 1. Supplementary overhead 115 kv circuits, location of generating stations, substations, pertinent rails, etc., are also shown. Market Street Steam Electric Station, in addition to being a generating station, also functions as a railway substation. Other railway substations are Polymnia, Dryades, Claiborne, Canal, and Valence. Stray railway currents in the vicinities of Market Street Station, Valence Substation, and Canal Substation exert very decided effects on the potentials to earth of the 115 kv steel pipe line.

Pipe and Cable

The pipe used was 6⅝-inch OD, ⅜-inch wall thickness, 25.03 lb./ft., Grade A, open hearth steel, seamless pipe in double random lengths. Pipe was mill coated using double thicknesses of plasticized type special coal tar enamel and double spiral wrappings of 15 lb./square, coal tar impregnated, asbestos felt. Plasticized type enamel was used rather than ordinary pipe line enamel because of expected high operating cable temperatures (158° F max.). To protect the interior of the pipe against rusting in transit, storage or installation, the ends were capped and the interior was coated with a rust inhibiting compound which was known to have a relatively low coefficient of friction in contact with the copper skid wires of the cable, and to have no significant harmful effect on the special oil used inside the pipe in conjunction with the cable.

The three single phase copper cables installed in the steel pipe line operate in a special oil which fills the pipe and is under pressure of 200 psi. The cables are each 600,000 circular mils, paper insulated. No lead sheathing was used on the cable, even in shipping. The rating of the line is 80,000 kva at 100 percent load factor.

Construction

To prevent oil leakage, the pipe line was of all welded construction with no permanent manholes in the 11-mile length. As a personnel safety precaution to guard against dangerous voltages under possible cable fault conditions, no linear insulated joints were permitted in the line. Very close visual and electrical inspection was given the pipe coating at time of installation. After burial, the coating was again checked over its entire length employing an interrupted tracing current, two exploring copper sulphate electrodes, and a vacuum tube voltmeter. Any significant coating defects thus located were dug up and repaired. Coating resistivity tests made on individual sections as the pipe was laid showed values ranging from 104,200 ohms/sq. ft. to 6,155,000 ohms/sq. ft. with an average of 1,321,200 ohms/sq. ft.

In order to be able to conveniently measure current flow and potentials along the pipe line, 38 electrolysis test points were established roughly every quarter mile (Figure 1), with details as shown in Figure 2. The various test leads were brought into a small metal test box on a nearby pole (Figure 3). Span lengths of 116 feet were selected because for this size pipe, the amperes/millivolt drop equalled unity. At each of the 38 test points a galvanic anode of commercially pure zinc (½" x 3" x 48") was buried vertically in a wet artificial backfill mix composed of 1 part of gypsum, 3 parts of native clay, motor mixed. Resistivity of the backfill mix was 250 ohms per cm^3.

★ A paper presented before South Central Region Meeting, National Association of Corrosion Engineers, Tulsa, Okla., Sept. 21, 1948 and Fifth Annual Conference, NACE, Cincinnati, Ohio, April 11-14, 1949.

* Electrolysis Engineer, New Orleans Public Service, Inc., New Orleans, Louisiana.

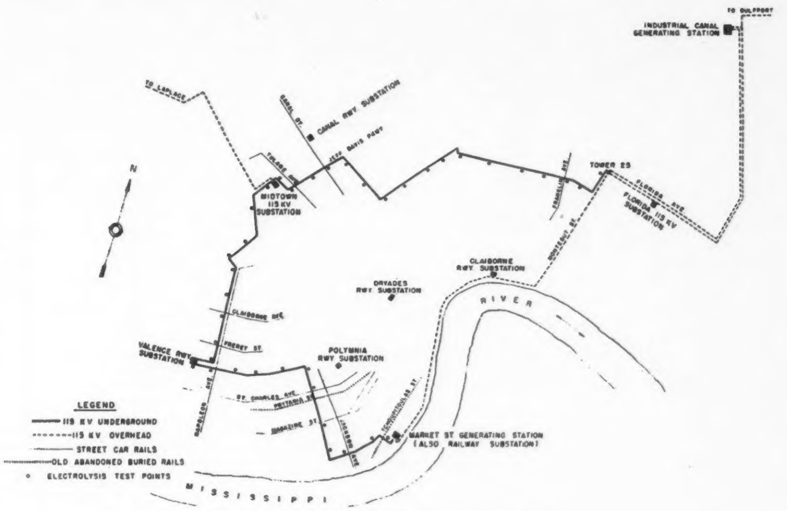

Figure 1—Routes of 115 kv transmission system.

Individual resistance measurements of these zinc anodes to earth showed values ranging from 2.0 to 25.0 ohms, with an average value of 7.51 ohms.

At Market Street 115 kv Substation, Valence Substation and at Tower 25, zinc anode beds were installed and tied to the line. Each of these consisted of ten commercially pure zinc anodes (½" x 3" x 96") buried vertically on 10-foot centers in the same type of artificial backfill mentioned above. Subsequent resistance to earth measurements of these anode beds disclosed the following values: Market, 0.36 ohms; Valence, 0.23 ohms; Tower 25, 0.17 ohms. The values of soil resistivity taken periodically along the route ranged from 350 to 3650 ohms per cm^3, averaging 1042 ohms per cm^3. The higher resistance soil was brown river sand near the Market Street end, grading down to low resistance Sharky clay from roughly Valence Substation to Tower 25.

In order to effectively apply subsequent cathodic protection, accidental electrical contacts with other metallic subsurface structures were avoided as the pipe was laid.

Discussion

The 38 individual zinc anodes and the three large zinc anode beds were originally installed for both cathodic protection and as a personnel safety measure to limit the voltage rise of the pipe under power faults. Calculated maximum power fault current was approximately 10,000 amperes. Because of the relatively lower impedance of the pipe line, practically all of this fault current would flow back to the generators at Market and/or Industrial Canal Stations over the pipe line rather than through the earth, and would cause voltage changes of the pipe with respect to earth which would be dangerous to personnel unless the line were rather solidly grounded, particularly at the two ends.

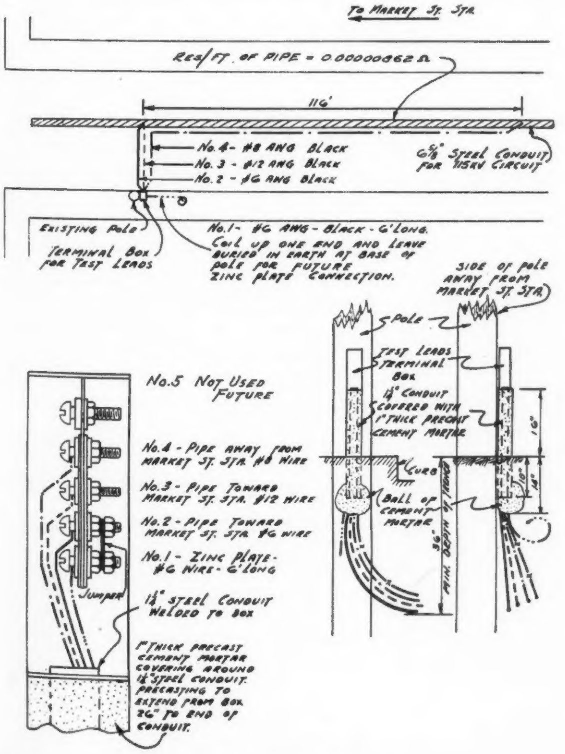
TO MARKET ST. STA.
RES/FT. OF PIPE = 0.00000862 Ω
116'
No. 4 - #8 AWG BLACK
No. 3 - #12 AWG BLACK
No. 2 - #6 AWG BLACK
6⅝" STEEL CONDUIT FOR 115KV CIRCUIT
EXISTING POLE
TERMINAL BOX FOR TEST LEADS
No. 1 - #6 AWG - BLACK - 6' LONG. COIL UP ONE END AND LEAVE BURIED IN EARTH AT BASE OF POLE FOR FUTURE ZINC PLATE CONNECTION.
SIDE OF POLE AWAY FROM MARKET ST. STA.
POLE
TEST LEADS TERMINAL BOX
1¼" CONDUIT COVERED WITH 1" THICK PRECAST CEMENT MORTAR
16"
CURB
10"
14"
BALL OF CEMENT MORTAR
36" MIN. DEPTH OF TRENCH
No. 5 NOT USED FUTURE
No. 4 - PIPE AWAY FROM MARKET ST. STA. #8 WIRE
No. 3 - PIPE TOWARD MARKET ST. STA. #12 WIRE
No. 2 - PIPE TOWARD MARKET ST. STA. #6 WIRE
No. 1 - ZINC PLATE - #6 WIRE - 6' LONG
JUMPER
1¼" STEEL CONDUIT WELDED TO BOX
1" THICK PRECAST CEMENT MORTAR COVERING AROUND 1¼" STEEL CONDUIT. PRECASTING TO EXTEND FROM BOX 26" TO END OF CONDUIT.

Figure 2—Terminal box.

An electrolysis profile was made just after the line was completed, and showed that the galvanic anode beds and individual zinc anodes were ineffective against the very steep electrical gradients in the earth caused by stray railway current drainage on the underground water mains, gas mains, cable sheaths, etc., in the vicinity of Market Street Station, Valence Substation and Canal Substation. This was true for all periods except when the railway load was very light, as at night. The results of this profile, greatly condensed for purposes of illustration in this paper, are shown on Figure 4. It will be noted that immediately adjacent to Market Street Station the 115 kv pipe was positive to the bare water pipes and bare copper station ground by from zero to 2.6 volts. Similar positive exposure existed in the immediate vicinity of Valence Substation and at Canal and Jefferson Davis Parkway (near Canal Substation), the 115 kv pipe line being positive to a highly drained water main by 0.40 volts. It will be noted that for the balance of the line between Market Street Station and Midtown Substation the 115 kv pipe was safely negative to the earth (as represented by the water mains) and was at least —0.90 volts to a copper sulphate electrode. However, the steep "vees" in the earth at the points mentioned near the railway stations required immediate attention because of their intensities. Furthermore, generally poor potentials

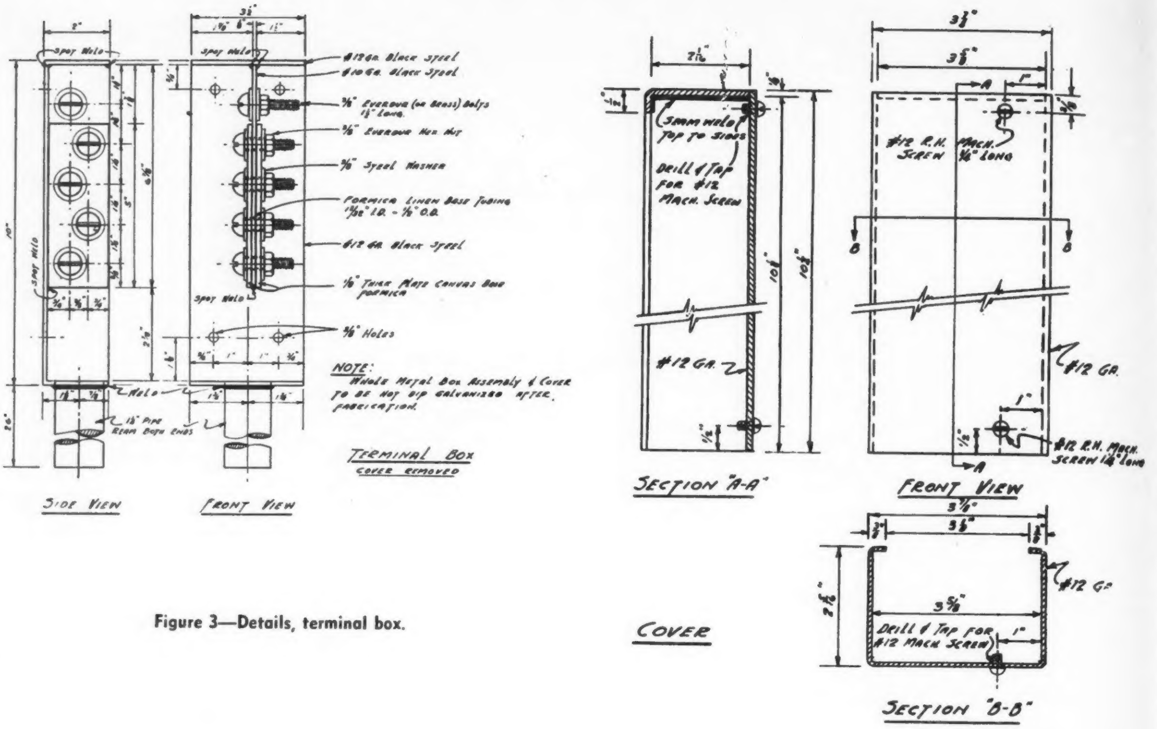
2"
3½"
1⅜"
1½"
Spot Weld
#12 Ga. Black Steel
#10 Ga. Black Steel
⅜" Everdur (or Brass) Bolts 1½" Long.
⅜" Everdur Hex Nut
⅜" Steel Washer
Formica Linen Base Tubing 13/32" I.D. - ½" O.D.
#12 Ga. Black Steel
⅛" Thick Plate Canvas Base Formica
⅜" Holes
NOTE:
Whole Metal Box Assembly & Cover to be hot dip galvanized after fabrication.
Weld
1½" Pipe Ream Both Ends
10"
26"
Terminal Box
Cover Removed
Side View
Front View
Section "A-A"
3mm Weld Top to Sides
Drill & Tap for #12 Mach. Screw
#12 Ga.
#12 R.H. Mach. Screw ½" Long
#12 R.H. Mach. Screw 1¼" Long
Front View
Cover
Drill & Tap for #12 Mach. Screw
Section "B-B"

Figure 3—Details, terminal box.

existed between Midtown Substation and Tower 25 because of accidental electrical contact between the 115 kv pipe line and the station ground at Midtown Substation, and also between the 115 kv pipe line and the grounded shield wire at Tower 25.

Because of the poor potentials mentioned above, and to minimize the value of ohmic resistance between the pipe and earth, it was decided to use stray railway current rather than galvanic current for cathodic protection, by tying in the 115 kv pipe to the underground structures which were drained to the railway negative buses at Market Station and Valence Substation, both of which stations operate on a 24 hour basis. Because Canal Substation shuts down at night (12:30 a.m. to 4:45 a.m.) it was undesirable to tie directly to drained underground structures in this area, because current would reverse during periods of station outages. For that reason, current was drained from the 115 kv line through a selenium rectifier and pumped to the street car rails on Canal Street.

Another electrolysis profile was made subsequent to stray current railway drainage, with results as shown on Figure 5. As might be expected, by pulling the potential of the 115 kv pipe down to at least the potential of the most highly drained substructures near the substations, the line was made considerably more negative to earth and to other underground structures than was desired. For instance, between Valence Substation and Market Station the 115 kv pipe line was found to be as high as 2.75 volts average below the water main. Similarly, voltages as high as 1.25 volts average existed between the 115 kv pipe and the water system between Valence Substation and the rectifier at Canal and Jefferson Davis Parkway, and as high as 1.0 volts average between the 115 kv pipe line and water system from the rectifier to the end of the line at Tower 25. The potential of the line was so negative that practically all of the

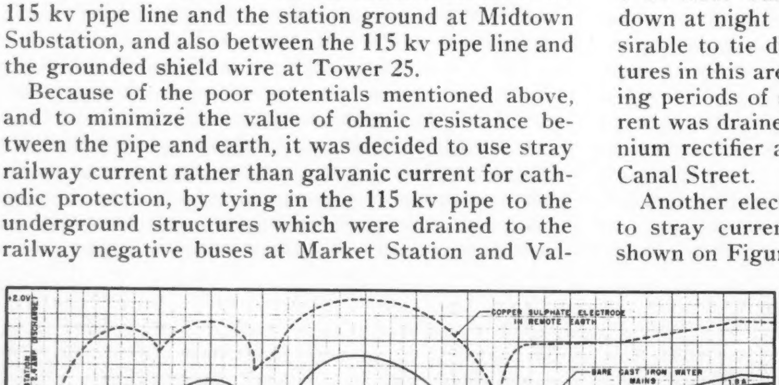

Figure 4—Electrolysis profile of 115 kv cable pipe line, with no drainage other than 38 individual zinc anodes and 3 zinc ground beds.

galvanic anodes collected rather than discharged current.

Serious complications were later encountered in the vicinity of Market Street Station, when for purposes of system improvements, the Jackson and later the Magazine Street car rails (Figure 1) were removed and the street cars replaced by electric trolley buses. In the interim between the removal of the Magazine rails and the beginning of the trolley bus service (about 4 or 5 months), the railway load at Market Station during light load conditions, such as over week ends and at night periods, was so light that inadequate drainage, hence poor potentials to earth were found to exist. Recording drops on totalizing shunts in the positive side of the railway machines showed that at times the current output actually reversed, meaning that the machines were running as d.c. motors fed from a neighboring substation, and not as generators. This meant that current instead of being drained from the underground structures (including the 115 kv pipe cable) was actually being pumped into these underground structures and discharged to earth. At such periods of reversal, simultaneous recording voltmeter charts showed potentials of pipe line to copper sulphate electrode in nearby earth of as low as —0.18 volts, a very dangerous figure. These poor night potentials affected not only the 115 kv cable but also other company owned underground structures such as lead cable sheaths, gas distribution system, deep water wells and miscellaneous underground facilities in the vicinity of the Market Street Station. All of these underground structures were tied together to the railway drainage bus, to the building frame of the station and to the station ground, and formed an underground metallic grid of extremely low resistance to earth, hence one requiring large currents to effect changes of potential with respect to the earth.

Briefly, then, the electrolysis problem at Market Street Station was one which required that the 115 kv pipe be tied to the railway drained underground structures because of steep daytime earth gradients caused by heavy railway loads. In the nighttime, insufficient railway load was available to pull down the potential of the combined underground structures to earth. Because of the rapidly fluctuating nature of the railway load, the use of an automatic switch to prevent reversals between the 115 kv pipe and the underground structures was considered impractical. The problem was solved by increasing the percentage of railway drainage in the area by forcing much of the Magazine and Jackson trolley bus currents to return to the station through earth paths, collecting on the underground structures for drainage, instead of using only conventional insulated copper return feeders. This was accomplished by tying to the negative side of the trolley bus systems two sets of abandoned buried street car rails on Prytania Street, and Tchoupitoulas Street, in order to increase the amount of stray railway current in the earth available for railway drainage around the station. Subsequent recording voltmeter charts between 115 kv pipe and

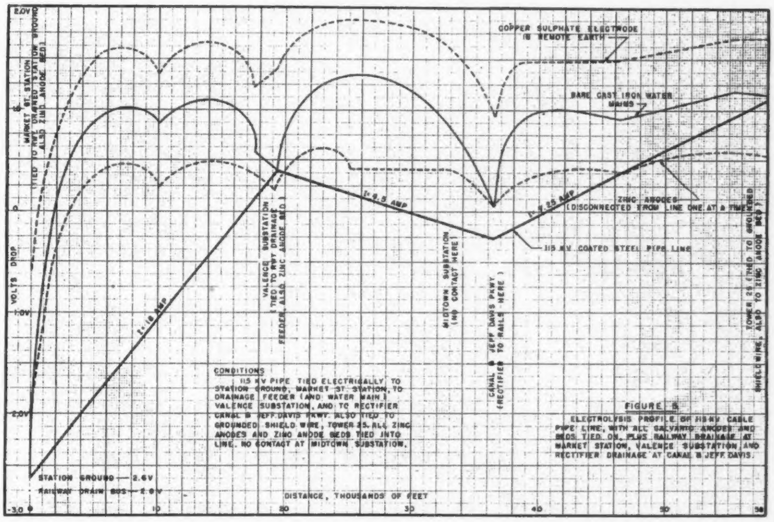

Figure 5—Electrolysis profile of 115 kv cable pipe line with all galvanic anodes and beds tied on, plus railway drainage at Market Station, Valence Substation and rectifier drainage at Canal and Jefferson Davis.

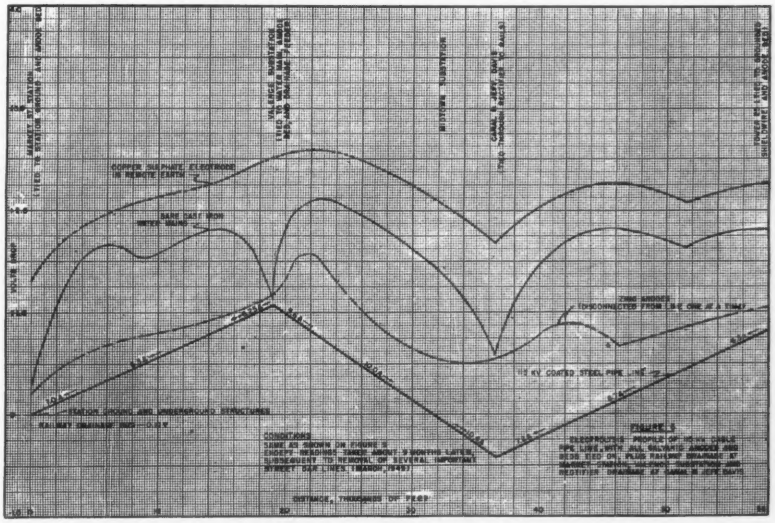

Figure 6—Electrolysis profile of 115 kv cable pipe line with all galvanic anodes and beds tied in, plus railway drainage at Market Station, Valence Substation and rectifier drainage at Canal and Jefferson Davis. Readings taken about nine months after those recorded in Figure 5, subsequent to removal of several important street car lines.

copper sulphate electrode revealed safely negative values over a 24 hour period.

In the latter part of 1947, the new Laplace 115 kv overhead line was tied into Midtown Substation for interconnection purposes with another utility. It was feared that if the lightning arrestors at Midtown Substation failed to function following a lightning stroke on the overhead line, the lightning stroke would be dissipated through spill gaps which supplement the lightning arrestors, and a 115 kv power surge would flow across the arc in the spill gaps. Because one side of the spill gaps is tied to the substation ground, the power surge would cause the substation ground to rise in potential with respect to the earth. Since the pipe line was not tied metallically to the substation ground (the accidental contact mentioned previously was located and removed), large differences of potential might be expected between the pipe line and the substation ground, with resulting danger to personnel.

This new Laplace 115 kv overhead feeder indicated the need for a tie at Midtown Substation between the substation ground and the pipe line, of sufficient capacity to carry the fault current until relaying protection cleared the fault (approx. 40 cycles or 2/3 second under the worst possible conditions) and yet of sufficient resistance that not too much current from the Canal Street rectifier would be picked up on the substation ground to load up the pipe line and militate against good potentials to earth.

Another electrolysis survey, plotted on Figure 6 (made under same general conditions as Figure 5, except that several more important street car lines had been removed) again indicated the desirability of lowering the existing high potential differences between the 115 kv pipe lines and the water mains.

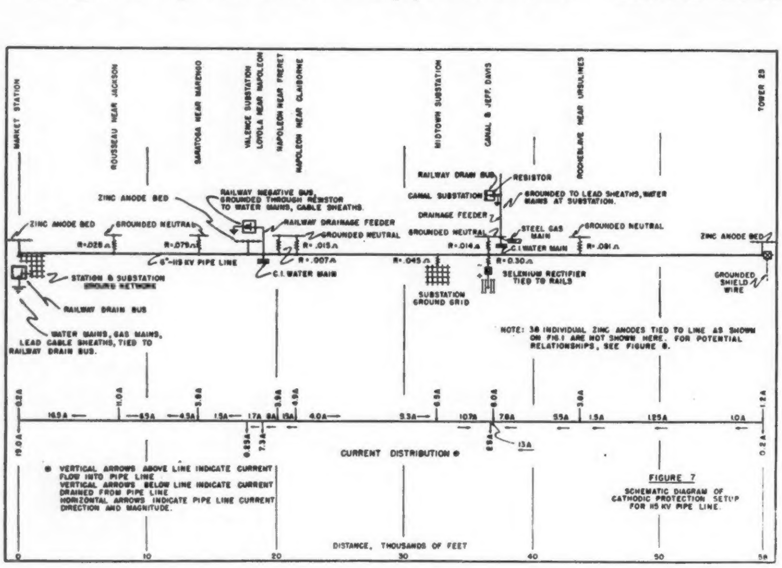
MARKET STATION
ROUSSEAU NEAR JACKSON
SARATOGA NEAR MARENGO
VALENCE SUBSTATION
LOYOLA NEAR NAPOLEON
NAPOLEON NEAR FRERET
NAPOLEON NEAR CLAIBORNE
MIDTOWN SUBSTATION
CANAL & JEFF. DAVIS
ROCHEBLAVE NEAR URSULINES
TOWER 25
ZINC ANODE BED
RAILWAY NEGATIVE BUS, GROUNDED THROUGH RESISTOR TO WATER MAINS, CABLE SHEATHS.
ZINC ANODE BED
GROUNDED NEUTRAL
RAILWAY DRAINAGE FEEDER
GROUNDED NEUTRAL
R=.028Ω
R=.079Ω
R=.015Ω
R=.007Ω
6"-115 KV PIPE LINE
C.I. WATER MAIN
STATION & SUBSTATION GROUND NETWORK
RAILWAY DRAIN BUS
WATER MAINS, GAS MAINS, LEAD CABLE SHEATHS, TIED TO RAILWAY DRAIN BUS.
RAILWAY DRAIN BUS
RESISTOR
CANAL SUBSTATION
GROUNDED TO LEAD SHEATHS, WATER MAINS AT SUBSTATION.
DRAINAGE FEEDER
GROUNDED NEUTRAL
STEEL GAS MAIN
GROUNDED NEUTRAL
R=.014Ω
C.I. WATER MAIN
R=.081Ω
ZINC ANODE BED
R=.045Ω
R=0.30Ω
SUBSTATION GROUND GRID
SELENIUM RECTIFIER TIED TO RAILS
GROUNDED SHIELD WIRE
NOTE: 38 INDIVIDUAL ZINC ANODES TIED TO LINE AS SHOWN ON FIG. 1 ARE NOT SHOWN HERE. FOR POTENTIAL RELATIONSHIPS, SEE FIGURE 8.
0.2A
11.0A
3.8A
3.9A
4.9A
6.9A
8.0A
3.0A
1.2A
16.9A
6.9A
4.9A
1.3A
17A
8A
19A
4.0A
9.3A
10.7A
7.8A
5.5A
1.5A
12.5A
1.0A
19.0A
0.85A
7.3A
6.8A
13A
0.2A
CURRENT DISTRIBUTION *
* VERTICAL ARROWS ABOVE LINE INDICATE CURRENT FLOW INTO PIPE LINE
VERTICAL ARROWS BELOW LINE INDICATE CURRENT DRAINED FROM PIPE LINE
HORIZONTAL ARROWS INDICATE PIPE LINE CURRENT DIRECTION AND MAGNITUDE.
FIGURE 7
SCHEMATIC DIAGRAM OF CATHODIC PROTECTION SETUP FOR 115 KV PIPE LINE.
DISTANCE, THOUSANDS OF FEET
0
10
20
30
40
50
58

Figure 7—Schematic diagram of cathodic protection setup for 115 kv pipe line.

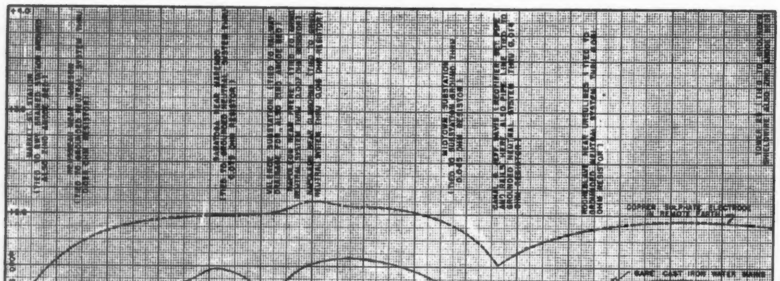

Figure 8—Electrolysis profile of 115 kv cable pipe line after all electrical adjustments were completed.

Accordingly, resistance bonds were installed at strategic locations between the 115 kv pipe line and the overhead system neutral (grounded directly to driven ground rods and to the water system and indirectly to the cast iron gas system) in order to load up the 115 kv pipe with sufficient current to cause its potential gradient to follow in general the gradients of the earth and the water system. Also, at Midtown Substation, a resistance bond was installed between the pipe line and station ground for the reasons of personnel safety mentioned above. The existing solid safety grounds to the grounded shield wire at Tower 25, to the station and substation ground at Market Station and Valence Substation were not disturbed. The schematic plan of safety grounding, cathodic protection and resistance bonds used is shown on Figure 7.

The final profile, Figure 8, shows electrolysis conditions of current and potential as they exist now that the resistance bonds have been installed. It will be noted that the potential differences between the 115 kv pipe line and the water system have been diminished to a general value of approximately —0.50-volt (as compared to a general value of —1.30 volts before the resistance bonds were added) in the areas some distance away from the drainage points. Similarly, potential difference measurements of pipe line to copper sulphate electrode generally approximate —1.10 volts (as compared to —1.80 volts before the resistance bonds were installed). Actually, the potential difference measurements between the pipe line and zinc anodes (removed from line one at a time) in so many cases averaged zero, that this line which was plotted on previous profiles was omitted on Figure 8. This means that the individual zinc anodes were more or less floating on the line, generally neither picking up nor discharging current. It was noted also that the potential gradient of the water system was generally less steep, as shown by a comparison of Figures 6 and 8, made a few days apart. This smoothing out effect may be due to the distributed drainage effect on the water system.

The relationships of currents on the pipe, in the resistance bonds, and at the drainage points are as shown on the lower portion of Figure 7. Because of the time element consumed in making the necessarily large number of readings and because of the highly fluctuating nature of railway loads, it is not to be expected that in an indicating survey, the distribution of current will check perfectly in conformity with Kirchoff's laws.

Assuming the worst possible condition of cathodic interference, consider a coincidence of the maximum average voltage (0.68v) between the 115 kv pipe line and the water mains, and the lowest coating resistivity (104,200 ohms/sq. ft.). Under this condition, it is evident that the current pickup through the earth between the 115 kv pipe and the water mains would be only 0.0000065 amperes or 6.5 microamperes per square foot of coated pipe. Even if the least favorable condition of voltage and coating resistivity extended throughout the entire 11-mile length, the total current pickup from the water mains through the earth to the coated 115 kv pipe line would be only 0.66 amperes. This is insignificant when it is considered that excellent drainage is afforded the underground structures at the points where the 115 kv pipe line is tied to the grounded neutral system. At the five points where these resistance bonds exist, currents ranging from 3.8 to 11 amperes (totalling 32.5 amperes) are beneficially drained from the underground structures, particularly the water mains.

Acknowledgment

Acknowledgment is made to the engineers of Ebasco Incorporated, and to Robert J. Kuhn, local consulting engineer, and to various members of the Engineering Department of New Orleans Public Service, Inc., for assistance rendered in the design, construction, and testing of the electrolysis features of this line.

Prevention of Corrosion By Means Other Than Protective Coatings★

By F. L. LaQUE*

THIS IS TO BE an introductory paper devoted to prevention of corrosion by means other than protective coatings. Whatever these means may be—and this includes protective coatings as well—their value will depend primarily on the soundness and completeness of their scientific foundation. Consequently, first importance attaches to the prevention of corrosion by learning more about its nature and mechanisms. Hardly less important is the recording of this knowledge so that all may make use of it. Then comes the exchange of information and experience so that development of principles and their practical application will benefit from attention from diverse scientific points of view and in a variety of services and industries.

This cultivated resource of scientific knowledge is one that differs from natural resources by being conserved most effectively by its most unrestricted and widespread dissipation. It is one that falls naturally within the field of interest of the United Nations. It is one that has grown through the efforts of scientists** in many lands who have published their work so that all may benefit from it. All have added to the understanding of the basic principles in ways that have enhanced the value of each other's contributions so that here truly we have an instance where the whole is much greater than the sum of its parts.

The attention being given corrosion at this Conference of the United Nations is, therefore, particularly appropriate. It represents an example of how the Nations of the world can expedite progress by their united efforts in bringing to light the basic principles upon which difficulties can be avoided. We have reason to hope, also, that similar international cooperation will have an equally good effect in alleviating problems in other fields as susceptible to improvement by concerted effort as has been the case with the prevention of corrosion.

The means of preventing corrosion other than by the use of protective coatings are so many and so varied in their application that the prescribed limitation of the length of this paper will permit only a sketchy treatment of each. The appended references to literature will have to be used by the reader who wishes to explore the details of any particular method.

Control of Environments

Humidity Control

In many instances the most effective and most economical means of controlling corrosion is to alter the environment so that it is made non-corrosive. Since practically all common corrosion processes require the presence of water, or water vapor, it is possible to prevent corrosion by eliminating water. It has been established[1] that when the relative humidity is kept below 30 percent corrosion will be negligible. If control of humidity is supplemented by the use of protective oils and greases, the critical humidity may be increased to 45 percent—as a matter of fact, some greases may be more effective with a little moisture in the air. For best results with control of humidity the surfaces to be protected should be cleaned as thoroughly as practical so as to eliminate hygroscopic "dirt" which may cause corrosion at relative humidities as low as 20 percent.[2]

Since the bulk of the moisture to be removed frequently is absorbed on the surfaces to be protected, the first stage of dehumidification will require much greater drying capacity than will be needed to maintain the desired level of humidity subsequently.[1]

Control of humidity may be accomplished by dynamic or static means. The former involves simply the use of air conditioning equipment to control the humidity in large spaces, such as the interior of ships or buildings—generally while they are laid up or not in use.[1]

Static means require sealing the equipment to be protected so that the atmosphere within the apparatus or envelope surrounding it may be kept dry by the use of a suitable desiccant, such as silica gel.[3] The desiccant is regenerated and replaced when it loses its power to maintain the required humidity as determined by an indicator, such as the change in color of cobalt sulfate crystals viewed through a window provided for the purpose.

Packaging envelopes for this purpose may be made of plastics which, however, do permit some transfer of moisture and require some means of venting through moisture absorbing breathers to avoid "ballooning" as the confined air becomes heated.[4] Metallic containers may be charged with dried air under a moderate pressure and, if desired, an inert gas, such as nitrogen, may be substituted for air.[5]

Deaeration

Corrosion of most metals can be prevented, or kept within tolerable limits, by removing oxygen from the environment. One of the oldest ways of accomplish-

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** At this point the author considered including the names of prominent students of corrosion throughout the world, but abandoned the attempt because there would not be enough room to list more than one name from each country. There was no good basis for choosing the individuals to be singled out in this way.

ing this is by consumption of oxygen by the corrosion of scrap iron introduced into the system for the purpose. A more reliable means is the common use of deaerators as generally applied to the treatment of boiler feed water. These devices get rid of carbon dioxide, ammonia and other non-condensible gases along with oxygen. It is possible to reduce the oxygen content of water below 0.01 part per million. For cold water systems reduction of dissolved oxygen to less than 0.3 part per million will suffice to prevent appreciable corrosion of steel.[6] Oxygen scavengers, such as sodium sulfite, are frequently added to water to take care of the last traces of dissolved oxygen.[7, 8, 9] When effective deaeration is combined with chemical adjustment of the water to about pH 11 it becomes practical to use steel for high pressure high temperature steam boilers without any significant amount of corrosion.[10]

Deaeration has also been applied successfully to the prevention of corrosion of steel pipe lines used to carry otherwise corrosive water for long distances.[6, 11]

Along the same line is the desirability of attention to pump and valve packings in circulating water systems—as in household heating units—to reduce the amount of make-up water required and to prevent continuous access of air. In the absence of such additions of air the oxygen initially present in a closed system and that introduced with small amounts of make-up water will be consumed by a relatively slight amount of corrosion.

The deaeration that accompanies vacuum evaporation or distillation may be effective also in reducing corrosion of the apparatus used for the processes.

In some special cases, deaeration may be undesirable and deliberate aeration is preferred. This may be the case with the use of stainless steels in contact with solutions—e.g., containing reducing acids—that are on the borderline between maintaining and destroying passivity.[12] Aeration may serve to preserve passivity that would be destroyed by deaeration.[13]

Inhibitors

In many instances it is possible to control corrosion by the introduction of a small concentration of some compound that stifles either the anodic or cathodic portions of the normal corrosion reactions, or both.[14] Most inhibitors function as chemically or physically absorbed films which either alter the electrochemical characteristics of the metal or serve as mechanical barriers to the normal corrosion processes.[15]

Organic inhibitors, frequently of a colloidal nature and of high molecular weight, are used regularly in acid baths for the descaling of steel.[16, 17, 18, 19] They conserve steel by reducing wasteful corrosion of the iron exposed by release of scale. They also reduce the amount of hydrogen evolution and thus avoid embrittlement and subsequent breakage of the pickled steel.[20, 21] Arsenic acts in a similar way and has been found to be quite effective in preventing corrosion by sulfuric acid.[22, 23] Organic inhibitors are used also as additions to the hydrochloric acid introduced through the steel tubing into oil wells to open up productive formations.

A frequent characteristic of organic inhibitors is that they are complex compounds containing nitrogen or sulfur.[18] However simple aldehydes are sometimes effective as exemplified by the use of formaldehyde to reduce corrosion of oil well tubing, casing and pumping equipment by brines containing hydrogen sulfide.[24]

A special use of inhibitors is for the prevention of the caustic embrittlement of steam boilers.[25] Quebracho extract and similar tannin compounds derived from waste sulfite pulp cooking liquor are used for this purpose, though sodium nitrate is believed to be even more effective.[26]

Chromates, dichromates, organic chromium compounds and nitrites are typical of inhibitors that function primarily electrochemically by inducing passivity. It is necessary that they be used in sufficient concentration to passivate all of the exposed surfaces, since otherwise they may serve to localize, rather than prevent, corrosion.[27]

These inhibitors are employed regularly to control corrosion in circulating water ranging from engine cooling systems to the large volumes of cooling water used in petroleum refining and other chemical plant processes.[28] Here a concentration of sodium chromate around 300 parts per million is usually adequate.

Sodium nitrite has been found to be particularly effective in preventing corrosion inside petroleum product pipe lines, thus maintaining their capacity for long periods.[29] Sodium chromate is used for the same purpose.[30]

Chromate inhibitors are well established for preventing corrosion by sodium and calcium chloride brines as used in refrigeration systems[31, 32] and for the treatment of water in air conditioning units, and well defined procedures have been worked out.[33] For calcium chloride brines the recommended concentration is 100 lbs. of sodium dichromate per 1000 cu. ft. of brine, or about 1.6 grams per liter. About twice this concentration is required for a sodium chloride brine.[31] They are also used in automotive cooling systems, including diesel engines where unusually severe corrosive conditions, perhaps aggravated by vibration effects may require concentrations as high as 4000 parts per million.

Silicates and phosphates, including hexametaphosphates and other polyphosphates, are used also very effectively to prevent corrosion in water systems.[34, 35] They appear to function through a filming effect which sometimes requires continuous additions of the inhibiting chemicals to maintain the films. Such film formation and repair is favored also by circulation and agitation. These compounds are especially useful in hot water systems above temperatures where the chromate type of inhibitor becomes unreliable. The polyphosphates are especially useful in preventing scale formation. Disodium phosphate is also used as an alternate to sodium dichromate for inhibiting corrosion by sodium chloride brines—the recommended concentration is 1.6 grams per liter.[31]

Another common use of silicates as inhibitors is to prevent corrosion of aluminum by alkaline detergents as used for cleaning aluminum vessels[36] and to prevent its use for containers for mildly alkaline products, such as shaving creams.

Though not exactly inhibition in the usual sense, it is common practice to add calcium carbonate to water to remove aggressive carbon dioxide and deposit protective scales and thus avoid corrosion of steel and iron pipe lines.[37, 38]

Another class of inhibitor is represented by the water soluble oils which are employed rather extensively in automotive cooling systems and as additions to prevent corrosion by anti-freeze compounds.[39]

Vapor phase inhibitors are volatile compounds that may be incorporated, for example, in packaging materials in order to maintain a non-corrosive atmosphere within a package. Similar compounds have been used effectively to prevent corrosion by carbon dioxide in steam heating and vapor return systems.[40]

What may be considered indirect inhibition of corrosion is the common use of additives designed to prevent decomposition of other substances in a way that would promote corrosion. This is exemplified by the use of antioxidants in engine lubricating oils and in organic antifreezes like ethylene glycol to avoid formation of corrosive substances or to neutralize acids that may develop. Additives in the form of polar organic compounds also may function by being adsorbed on the metal surfaces so as to act as a barrier or repellant to corrosive water.[41]

Cathodic Protection

One of the most effective means of preventing or arresting corrosion is by the application of what is called cathodic protection. This is based on the principle that most corrosion of practical importance is electrochemical in nature and results from the flow of current through an electrolyte between areas of different potential which may exist on the surface of a single metal or between two or more different metals. The flow of current and its resulting corrosion can be eliminated by bringing all surfaces to the same potential. This can be accomplished in most cases by discharging current on the more noble (cathodic) surfaces so as to achieve their cathodic polarization to the potential of the adjacent anodes.[42] The importance of what goes on at the cathode in such instances and the fact that the metal to be protected is made the cathode of the electrical circuit give rise to the use of the term cathodic protection to describe what is accomplished.

Cathodic protection is not new. It was introduced by Sir Humphrey Davy in 1824,[43] when he endeavored to control corrosion of the copper sheathing on war ships by the current generated by the galvanic corrosion of zinc. This probably was the start of the traditional use of zinc, especially in marine engineering, to protect the hulls and shafts of steel ships in the vicinity of bronze propellers. Zincs are used regularly also for the reduction of corrosion in steam boilers and in various types of condensers and other heat exchange apparatus in which corrosion by salt water is encountered. More recently efforts have been made to put such use of "zincs" on a sounder technical basis with respect to the size, distribution and purity of the zincs used. The principal difficulties are to insure that the amount of current generated by corrosion of the zinc will be sufficient and that it will be distributed adequately to all surfaces requiring protection. This latter requirement is extremely difficult, if not impossible, to achieve in tubular apparatus where the zincs or other anodes must be located outside the tubes while the corrosive liquid passes through the tubes. It is a general rule that a protective current will not flow into a tube much beyond one tube diameter past the end of the anode. Where there is considerable deposition of insulating films on cathodic surfaces—as occurs in sea water—the zone of protection will be extended gradually to greater distances from the anode and protection by the coating will persist through interruptions in the flow of protective current and for a time after flow of current ceases.

Magnesium and aluminum are used in much the same way as zinc as galvanic anodes in cathodic protection processes.

An important advantage of magnesium is the higher effective potential that is developed.[44]

In order to develop effective anodic potentials it is necessary to alloy aluminum.[45] Alloys suitable for anodes are under development and some, containing zinc, are now recommended for limited applications with relatively noble metals e.g. lead cables. With zinc, impurities, especially cadmium and lead, should be restricted to very low limits to avoid the formation of insulating films which may reduce current output very quickly. Zinc of 99.99% purity is recommended.[45] Magnesium is used either as the electrolytic cell product or, prefarably, alloyed with aluminum (6%) and zinc (3%).[44]

The theoretical economic relationships among zinc, aluminum and magnesium are indicated by the following data which should be adjusted to take into account the anodic efficiencies of the metals in particular environments. These anodic efficiencies can be adjusted favorably by the proper choice of backfill[46, 47] to surround the galvanic anodes in the protection of underground structures and, in some instances, by adjustments in the compositions of the anodes.

ELECTROCHEMICAL EQUIVALENTS OF GALVANIC ANODES

Metal	Ampere Hours Per Pound of Metal Theoretical	Estimated from Expected Efficiencies
Magnesium	997	600
Aluminum	1352	675
Zinc	372	335

Outside of the use of zincs for the cathodic protection of steel ships, the first uses of the practice in other fields grew from the efforts to counteract corrosion of underground pipe lines and other structures by currents that "strayed" from street railway systems. The bonding of such structures to the negative side of the power generators was followed by the installation of auxiliary anodes distributed so as to provide a flow of protective current to the structures to be protected.[48, 49]

By far the most important application of cathodic protection has been in connection with the thousands of miles of underground oil, gas and water pipe lines, and power and communication cables. In most instances cathodic protection is used as a supplement to the usual built up organic and fibrous coatings which serve to reduce the amount of current required and achieve its uniform distribution from widely spaced anodes.

The sources of the required current may be rectifiers, oil or gas engine driven generators, wind driven generators or, under appropriate circumstances, galvanic anodes of magnesium, zinc, or aluminum.

Another common application of cathodic protection is in connection with municipal or plant water storage tanks.[50] Here a rectifier is generally used as the source of current which is applied through aluminum, steel or platinum anodes suspended in the tank and its water column. Here, too, cathodic protection is ordinarily supplemented by, or supplements, the conventional organic coatings used in tanks of this sort.

A relatively new application of cathodic protection of domestic importance is the installation of magnesium anodes to prevent corrosion of galvanized steel hot water tanks so as to extend their life and avoid the so-called rusty "red" water.[51]

Since only the high spots of cathodic protection can be mentioned here, the reader is referred for details to a recent publication of the National Association of Corrosion Engineers and the Electrochemical Society.[52]

Design

Attention to design factors in preventing corrosion represents simply a combination of knowledge of the nature of corrosion and corrosion processes and the common sense application of that knowledge.

Variations from point to point in the temperature, velocity, concentration and aeration of a solution represent common sources of corrosion currents. Consequently, the design and construction of apparatus should be such as to avoid opportunities for such heterogeneity of the environment to develop.[53] This means that crevices between faying surfaces or under wet porous materials, sharp corners, deposits, loose or discontinuous scales, obstacles to flow, and other causes of local turbulence and hot or cold spots should be avoided, or removed as they develop, as factors that may give rise to destructive concentration cells. If crevices cannot be avoided in construction, then they should be sealed by suitable caulking compounds, being careful, however, to use caulking materials that do not form harmful crevices on their own account along their outer edges.

As a general rule, alloys that depend on passivity for corrosion resistance benefit from a moderate degree of turbulence which will keep the surface free from clinging substances and bring passivating agents, such as dissolved oxygen, to the alloy surfaces. Other alloys that are protected by relatively gross corrosion product films that may not be retained under turbulent conditions may suffer serious damage if velocity conditions become too severe. The point is illustrated by a comparison between brass and stainless steel as used in a tubular heat exchanger in which salt water passes through the tubes. If brass tubes are used, best results in terms of tube life will be secured if the velocity is held to a maximum of 5 feet per second, whereas when stainless steel tubes are used the velocity should be set at 5 feet per second minimum.

The corrosion accelerating effects of galvanic action are too well known to require special emphasis. The galvanic relationships among metals and alloys vary somewhat depending on the nature of the environment, but are generally known well enough to serve as a guide for avoiding combinations that are far apart in a galvanic series.[54] In many instances, the galvanic effect is roughly proportional to the ratio of the area of the cathode to the area of the anode in the couple so that it is necessary to avoid combinations where the cathode area is relatively large.[55] The reverse relationship of areas frequently can be tolerated as exemplified by the use of corrosion resisting alloy fastenings in ordinary steel assemblies, e.g., flange bolts in pipe joints.

The principle of relative areas also leads to caution in the use of coatings to control galvanic effects. It is necessary to avoid incomplete covering of the anode with resultant concentration and intensification of the galvanic effect at bare spots. Better practice is to coat the cathode so as, in effect, to take it out of the system, or to coat both the anodic and cathodic portions of the couple.[56]

It is bad practice to use threaded connections between dissimilar metals—brazed or welded joints are much better. Where connections of this sort must be made—as in piping systems—the first section of the less noble metal at the joint should be made with an extra heavy wall and should be a short section located so that it can be replaced readily. Spare replacement or "waster" pieces should be held in reserve and, if practical, kept close to the point where they will have to be used.[57]

Similarly, where galvanic couples are involved in vessel construction, the thickness of the less noble metal should be increased in the vicinity of the joint, as by the use of "double plates" to build up the thickness of metal in the critical region.

It is, of course, also possible and desirable to avoid galvanic action by the use of electrical insulation between the dissimilar metals.

As in the case with normal corrosion, galvanic corrosion can be overcome by cathodic protection which may be provided by a rectifier or a replaceable sacrificial galvanic anode. Galvanic effects may also be reduced by the use of inhibitors which either stifle the reaction or passivate the less noble metal to the potential of the more noble one.[58, 59, 60]

As an extension of the principle of avoiding crevices, etc., as seats of concentration cells, there is the simple practice of eliminating opportunities for corrosive liquids to collect and remain in pockets where they may become more concentrated and more corrosive by gradual evaporation. For example, the bottoms of tanks should be sloped and the drains located so that when drained the tank will be emptied completely without leaving any pools of corrosive liquid. Similarly, thorough ventilation is frequently desirable so as to allow the metal surfaces to be dried as quickly as possible by the circulation of air. Such occasional drying out may also permit corrosion products to develop protective characteristics that would never appear if they remained moist continuously. For example, it is good practice to support tanks on legs rather than to let them rest on the ground or on a wet floor.

Hollow compartments or reinforcements should be provided with openings through which corrosive liquids or condensed moisture can drain freely. For the same reason, the edges of lapped plates should be chamfered to facilitate drainage and, where practical, the laps should face downwards so that moisture will not have a chance to lie in the joints.

Where corrosion occurs as a result of condensation of corrosive vapors, as from flue gases, it is possible either to prevent corrosion by maintaining the metal surfaces at temperatures above the dew point of the gases or to control the cooling of the gases so that condensation will occur at some non-critical point or where its corrosive effects can be taken care of at minimum cost.

Some combinations of metals and corrosive media give rise to corrosion difficulties only within certain critical ranges of concentration or temperature which, if known, can be avoided in the carrying out of processes or permitted to exist for a minimum proportion of the time of the operations.

Some materials suffer loss in corrosion resistance as a result of effects of heat as encountered in welding or stress relief annealing operations. Obviously these factors must be considered in choosing the alloy and method of fabrication. Where necessary, the original design must be chosen to permit the practical carrying out of any heat treating operations that must follow fabrication. If such heat treatment after fabrication is not feasible, then the material used and the method of fabrication must be chosen so that satisfactory corrosion resistance will be achieved in the "as fabricated" condition of the metal.[61, 62, 63]

Adjustments of Composition

One of the most effective means of increasing the durability of the elemental metals is to combine them in alloys or to control their minor constituents so as to achieve the corrosion resisting properties desired. The improved corrosion resistance may involve combining metals in substantial proportions, the addition of elements in minute proportions to achieve specific effects, on the purposeful exclusion or close control of undesirable minor constituents.

The stainless steels provide the most spectacular modern example of improving the durability of a metal—in this case iron—by the addition of the alloying elements chromium and nickel which are frequently supplemented by such other elements as molybdenum, columbium, titanium, silicon, copper and tungsten added for specific purposes. It is not uncommon for these alloys to demonstrate resistance to corrosion as much as 100,000 times that of ordinary iron. The extra durability thus provided is effective in conserving resources, first by prolonging the useful life of equipment, and second by permitting the use of thinner and lighter sections, thus saving raw materials in the first instance. There are also supplementary advantages in savings in fuels and energy in instances where the alloys are used for transportation equipment or other apparatus that must be moved by power of some sort.

Particular mention is made[61, 62] of the use of additions to stainless steels of titanium or columbium to overcome a detrimental effect of carbon after welding or other operations that involve holding the alloys for appreciable periods within a critical temperature range from about 650° to 1500° F. Recently means of achieving the desired result by manufacturing alloys with a carbon content not more than 0.03 percent have been developed on a practical scale.[64, 65] This will decrease the requirements of titanium and columbium for this purpose and will increase their supply available for other uses.

The addition of molybdenum to the stainless steels effects a tremendous improvement in their resistance to specific environments. This improvement may be as much as a thousand-fold and naturally not only extends the fields of application of the alloys, but also extends their life with consequent conservation of their constituents.

Less spectacular, but nevertheless very important, is the improvement in the resistance of iron to corrosion by the atmosphere that can be secured by the controlled addition of small percentages of such elements as copper, phosphorus, nickel, chromium and silicon in various amounts and combinations.[66] Probably the most powerful effect is that of copper. In an industrial or marine atmosphere an increase in the copper content of an open hearth iron from 0.005 percent to 0.05 percent will result in a ten-fold improvement in corrosion resistance.[67] Further additions of copper will have a moderately beneficial effect. Larger amounts of nickel and chromium alone or together and with or without copper and other elements will effect still further increases in corrosion resistance which can make the alloy steels about twice as durable as copper steel as measured under the usual atmospheric corrosion testing conditions in terms of weight loss over a test period of three or four years. The rusts that form on the alloy steels become very protective when they have a chance to dry out so that progressive corrosion almost ceases after exposure for about five years.[68, 69, 70] The alloying elements that confer the improved resistance to corrosion also strengthen the steels considerably so that lighter sections can be used with consequent savings in weight which are especially attractive in transportation equipment such as railroad cars, bus and truck bodies and tanks used for fuel transportation. The greater initial strength of these steels is important also with respect to the strength that remains even after some corrosion has occurred.

With the older alloy systems, such as the brasses and bronzes, there has been built up a tremendous reservoir of knowledge and experience which serves as a reliable guide to their proper selection for particular services. This, therefore, provides the best basis for the conservation of their major constituents—copper, zinc, tin and aluminum. A noteworthy and fairly recent advance in the durability and usefulness of alloys of this class are the incorporation of small amounts of arsenic, antimony or phosphorus (usually in amounts under 0.05 percent) to prevent dezincification of copper zinc alloys containing more than 15 percent zinc.[71, 72] Another improvement has been the addition of about 2 percent aluminum to a 22 percent zinc, balance copper, alloy so as to effect a considerable increase in resistance to the corrosive and erosive effects of salt water at high velocity, sometimes referred to as impingement attack.[73]

In the copper nickel system there are the older alloys represented by Monel (70 percent nickel) at one end, and the nickel silvers (10 to 20 percent nickel) at the other which are well established and used on a basis of selection in terms of properties and performance that insures best use and conservation of their basic constituents. Important newcomers in this field are the cupro nickels, and especially the 30 percent nickel alloy that has become the standard material for marine condenser tubes where maximum reliability is required as in naval vessels and large merchant ships.[74, 75] The performance of the 70:30 cupro nickel alloy is improved by the controlled addition of a small percentage of iron,[76] i.e., from 0.25 to 1 percent, and sometimes as much as 2 percent, which is believed to be especially useful where badly polluted waters must be provided for.

The beneficial effect of iron in the 30 percent nickel alloy has led to the use of the same element in alloys of lower nickel content, and especially the 10 percent nickel alloy which is coming into common use to resist corrosion by sea water.[76]

The considerable attention that has been given the effects of composition on the corrosion resistance of aluminum and its alloys has provided a sound basis for selection of the proper alloy for particular purposes. This insures that aluminum itself will not be wasted by preventable corrosion and, also, permits the substitution of aluminum in some cases for other metals that might be wasted in applications where they would be dissipated by corrosion.

In the case of magnesium, the principal advance that has been made in increasing its durability in corrosive environments has been the establishment of specification limits on elements that are detrimental to corrosion resistance and the addition of elements that overcome bad effects of other constituents.[77]

Limitations of space permit only passing reference to other metals, such as lead and zinc and the precious and semi-precious metals like gold, platinum, silver and tantalum. The application of all of these to defeat corrosion has a sound technical basis. All of them are being used effectively where their specific properties dictate their use and where by resisting corrosion successfully they, in effect, serve to conserve other metals that would be less durable in such applications.

As a supplement to the few specific references to literature on particular points there is appended a list of books that deal with corrosion and which will provide a reliable guide to those who wish to review the general subject or any of its phases in greater detail.

Acknowledgment

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Books on Corrosion and Its Prevention

I. In English.

1. The Corrosion Handbook, edited by H. H. Uhlig, sponsored by The Electrochemical Society, Inc., published by John Wiley and Sons, Inc., New York, New York, U.S.A., 1948.
2. Metallic Corrosion Passivity and Protection—U. R. Evans —published by Edward Arnold and Co., London, 1946. Longmans, Green and Co., New York.
3. The Corrosion of Iron and Steel—J. C. Hudson. Published by Chapman and Hall, London, 1940.
4. Protective Films on Metals—E. S. Hedges, Published by Chapman and Hall, London, 1937.
5. Corrosion Resistance of Metals and Alloys—R. J. McKay and R. Worthington—American Chemical Society Monograph No. 71. Published by Reinhold Publishing Co., New York, New York, 1936.
6. Corrosion—Causes and Prevention—F. N. Speller. Published by McGraw-Hill Book Co., New York, New York, 1935.
7. Soil Corrosion and Pipe Line Protection—Scott Ewing. Published by American Gas Association, New York, 1938.

II. In German.

1. Die Zerselzungserscheinungen der Metalle—G. Schikorr. Published by J. A. Barth, Leipszig, 1943—reprinted by Edwards Bros., Inc., Ann Arbor, Michigan.
2. Mesung und Verhütung der Metallkorrosion—F. Tődt. Published by Walter de Gruyter and Co., Berlin, 1941. Reprinted by Edwards Bros., Inc., Ann Arbor, Michigan.
3. Die Korrosion Metallischer Werkstoffe—O. Bauer, O. Krőhnke and G. Masing. Published by S. Hirzel Leipszig. 3 Volumes—1936, 1938, 1940.

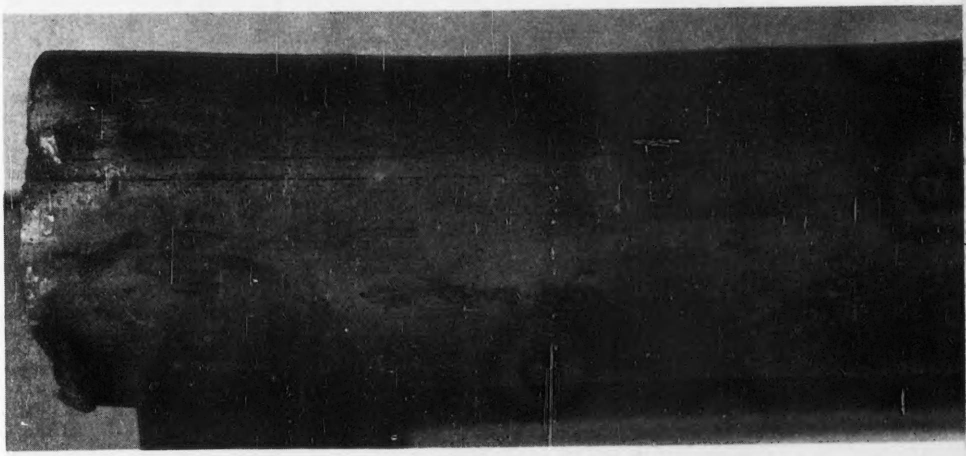
III. In Spanish.

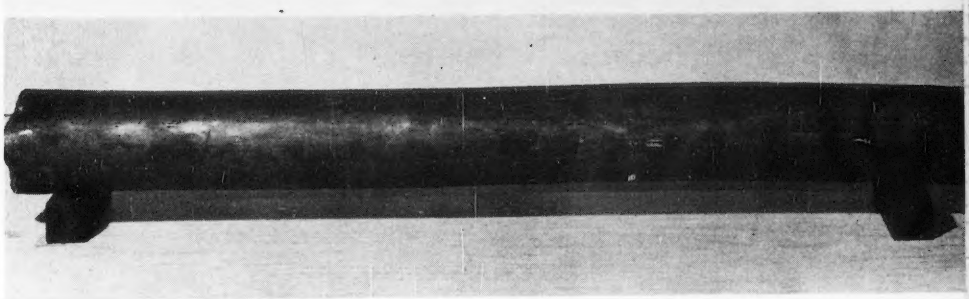
1. El Problema de la Corrosion Metalica—E. Jimeno. Published by Inst. Espanol de Oceanografia, Madrid, 1947.

IV. In Russian.

1. "The Theory and Methods of Investigating Corrosion of Metals," by G. W. Akimow. Published by Academy of Science, U.S.S.R. Moscow, 1945.
2. "Acid Resistant and Heat Resistant Stainless Steels," by F. F. Khimoushin. Published by the State Scientific Publishing Office. Moscow, 1940.
3. "Corrosion of Metals With Oxygen Depolarization," by N. D. Tomashov. Published by the Academy of Sciences, Institute of Physical Chemistry, U.S.S.R. Moscow, 1947.

Topic of the Month





Galvanic Corrosion of Lead-Sheathed Cable

Corrosion on 12,000-volt lead sheathed cables in an underground electrical distribution system is illustrated. Electrolysis in this case is attributed mainly to galvanic action set up by metallically bonded bare copper neutrals and copper grounded rods to lead sheath in areas of low resistance soil or duct waters.

NACE News

North East Region Sets Goal of 1000 Members And Two Added Sections

Divisions of operation were assigned to members of the North East Region Board of Trustees at a meeting December 6, and steps were taken to organize new sections of the association in the New England area and Western New York area. The board also set a membership goal of 1000 in North East Region from the present 625. The meeting was held at Hotel Stafford, Baltimore, Md.

A calendar for meetings of the trustees for the coming year in January, March, May, September, October and December will be organized soon.

Divisions Assigned

The following trustees were assigned areas of responsibility in conducting the business of the region, and asked to report to the board at each meeting:

Membership—Active, corporate, methods for increasing, new sections. —H. L. Hamilton.

Nominations—Region, section; knowledge of personalities, qualifications of members. —R. H. Coe.

Program Coordination—Dates of region and section meetings, conflicting dates, types of meetings and programs, subjects, long term program. —T. P. May.

Publicity—Corrosion, trade journals, technical journals, newspapers. —H. R. English.

Rules—Region and section by-laws, terms of office. —L. B. Donovan.

Term of Office Set

Respecting a question over the unexpired term of office of E. P. Noppel as director the secretary was instructed to advise A. B. Campbell, stating that North East Region was of the opinion R. H. Lynch, filling the expired term would remain in office until the last day of the annual meeting in 1951; that a nominee to succeed in the office would be named in the latter part of 1950; and that the candidate elected from this nomination would assume office on the last day of the annual meeting in 1951 and remain in office to the last day of the annual meeting in 1954.

Sections were requested to submit financial reports as of December 15, 1949.

It was suggested New England be added to the mailing list of Metropolitan New York Section pending organization of additional sections.

Present were N. P. Peifer, A. S. Brookes, T. P. May, H. L. Hamilton, E. F. Wolf, G. E. Best, E. R. English and L. B. Donovan.

Election of region officers has been reported previously.

Association By-Laws Provide That Delivery of

CORROSION

Be discontinued to members of the association who are three months in arrears in payment of dues. If you failed to receive your statement regarding your 1950 membership being due January 1, or if you have overlooked paying your dues and wish to continue receiving CORROSION, your remittance should be at Central Office NACE not later than March 15, 1950.

A. E. Storm Is Elected San Francisco Chairman

Arthur E. Storm of Tide Water Associated Oil Co. was elected chairman of San Francisco Bay area section at its December 13 dinner meeting. R. J. King, Standard Oil Co. of California and William R. Staples, Carpenter Steel Co., were named vice-chairman and secretary-treasurer, respectively.

"Petroleum Refinery Non-Destructive Testing," was the topic of an address by Glenn C. Vergne of Tide Water Associated Oil Co. at the December 13 meeting. Mr. Vergne discussed various methods and instruments used in non-destructive testing, including Magnaflux, Zyglo, Audigage, trepanning, leak vibroscope, vacuum seam tester and others. A motion picture "Pipe Line in Arabia," showing aspects of the Trans-Arabian pipe line was presented by Richard Finnie of Bechtel International Corp.

Approximately 50 members and guests were present.

Salt Lake Section Adopts By-Laws December 14

By-laws of the Salt Lake Section were presented to and adopted by the membership at a December 14 meeting attended by 9 members and 7 guests. Bad weather interfered with attendance.

Dr. W. Martin Fassell, Jr., of the University of Utah Experiment Station gave a talk on "High Temperature Oxidation of Magnesium and Magnesium Alloys."

A 30-minute color motion picture "Gas Fields of the Mountain Fuel Supply Co.," showing gas fields in Wyoming, Colorado and Utah was shown.

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Extensive Tables of the confluent hypergeometric function $F(n/2, 1/2; x)$ and related functions, prepared by the National Bureau of Standards, are now available from Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C., 35 cents per copy.

Equipment Failure Is Topic at St. Louis

Scheduled topic at the January 16 meeting of Greater St. Louis Section at Garavelli's Victoria Tea Room January 16 at 7:45 p.m. was a talk by Frank W. Davis, chief metallurgist with E. B. Badger and Sons Company, Boston, Mass. Mr. Davis' topic was "Some Aspects of the Design and Fabrication of Equipment for Corrosion Service," which included data on a number of unusual equipment failures attributable to corrosion and the methods employed to solve the problems involved.

Mr. Davis, a graduate of Lehigh and Nebraska Universities, has had more than 30 years' experience in metallurgy. He is active in NACE.

Thirty members and 28 guests heard Geo. B. McComb of Standard Pipeprotection, Inc., St. Louis, speak on pipe line protection and show two technical motion pictures, one of the laying of the "Big Inch" pipe line and the other the extent to which the city of Los Angeles went to coat and protect its underground water distribution system at the December 19 meeting.

Guests at the meeting were Water Commissioner T. J. Skinker and Chief Engineer, Water Division J. B. Dean of the city of St. Louis.

Mr. McComb's talk, "Mechanical Application of Protective Coating Systems to Underground Pipe Lines" covered materials and methods for protecting underground pipe lines. The film relating to the Los Angeles water system showed the methods used to coat with coal tar enamel the inside of steel pipe.

Attendance between 60 and 80 at each section meeting is indicated.

Vinyl Coatings Topic At Houston Meeting

G. L. Pitzer, Carbide and Carbon Chemicals Corp., Texas City, Texas gave an illustrated address to more than 70 members and guests at the January 10 dinner meeting of Houston Section, National Association of Corrosion Engineers. Subject for the evening was "Vinyl Coatings." Mr. Pitzer discussed formulation of vinyl coatings, including control of desired characteristics by regulation of conditions during polymerization of vinyl chloride and vinyl acetate. Use of butyral wash primers to condition a metal surface also was mentioned.

V. L. Larson, Bakelite Corp., St. Louis, assisted the speaker in answering inquiries following the address.

The nominating committee reported on selection of candidates for 1950 officers to be balloted on by members.

Questions Are Solicited For Two Corrosion Panels

Questions now are being collected from Association members for submission to General Corrosion and Pipe Line Corrosion Round Table Panels at the 1950 NACE Conference. Reply post cards have been mailed to members asking for inquiries in advance of the conference, because it has been learned at similar panels held elsewhere by NACE that replies to many questions cannot be given adequately without opportunity to study them beforehand. Questions from the floor during the discussions also will be welcomed.

The General Corrosion Round Table and the Pipe Line Protection Round Table are scheduled tentatively to be held simultaneously Friday morning, April 7 solely for the purpose of giving members attending the conference the opportunity to ask a panel of experts questions not covered by the formal papers or to air any topics not so covered.

Questions for both panels should be in sufficient detail to permit full evaluation of the problem. Those who prefer to do so are invited to address questions on General Corrosion Problems to Mr. F. L. LaQue, Corrosion Engineering Section, Development and Research Div., The International Nickel Co., Inc., 67 Wall Street, N. Y. C. and on Pipe Line Problems to Mr. E. J. McElhatton, Panhandle Eastern Pipe Line Co., 1221 Baltimore Ave., Kansas City, Mo.

Six Short Course Lectures Reproductions Issued

Registrants, instructors and several others who have expressed interest in them have received by mail copies of six papers, representing seven of the lectures delivered during the Short Course in Corrosion at University of Texas, Austin, September 12-16, 1949.

The lectures distributed were: Protective Coatings, by W. F. Fair, Jr.; Corrosion Resisting Metals and Alloys, by F. L. LaQue; Theoretical Cathodic Protection, by Lyle R. Sheppard; Practical Application of Cathodic Protection, by A. W. Peabody; Chemical Treatment in the Prevention of Corrosion by H. E. Waldrip and Outline for Lectures in Fundamentals by Norman Hackerman.

Still to be reproduced are lectures given by L. G. Vande Bogart and F. A. Prange.

Corrosion
News Deadline:
10th of Month
PRECEDING
Date of Issue

New Manuscript Titles for St. Louis Meeting Papers Under Consideration Are Listed

MEMBERSHIP CARDS AVAILABLE

Association members in good standing will be issued on request a membership card in the National Association of Corrosion Engineers. Address requests to A. B. Campbell, Executive Secretary, 919 Milam Building, Houston 2, Texas.

Four Booths Unsold

Four booths for the 1950 exhibit to be held concurrently with the 1950 conference at Jefferson Hotel, St. Louis, Mo., April 4-7 remained unallocated on January 13. Seventy-three booths had been allocated to 57 companies as of that date, among which were several new exhibitors.

In connection with the conference and exhibit the annual March Conference Issue of CORROSION magazine will include information pertaining to the content of exhibits. Increased interest and attendance to the exhibit is expected to result from the publication of this information.

New titles of technical papers under consideration for presentation at the 1950 NACE Conference in St. Louis, April 4-7 have been revealed as follows:

Chemical Industry Symposium—"Corrosion of Metals by Insecticidal Solutions," by George S. Cook and Nancye Dickinson, Engineer Research and Development Laboratories, The Engineer Center and Fort Belvoir, Fort Belvoir, Va.

Fresh and Salt Water Corrosion Symposium—"Potentials Set Up by Thermal Gradients in Iron Immersed in NaCl Salutions," by H. H. Uhlig, Massachusetts Inst. of Tech.

"Electrochemical Behavior of Zinc and Steel in Aqueous Media, Part II," by R. B. Hoxeng, Case Inst. of Tech.

Protective Coatings Symposium — "Flame Sprayed Plastic Coatings," by Dr. Goldberg, Schori Process Div., Ferro-Co Corp.

Pipe Line Corrosion Symposium — "Surface Potential Method of Corrosion Survey on Pipe Lines," by O. W. Wade, Great Lakes Pipe Line Co., Independence, Kansas.

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Notices of future meetings of NACE subdivisions are carried monthly under the heading "NACE Calendar" in each issue of CORROSION magazine. Notices for this column should be sent to Central Office.

Speakers at Second N. Y. University Varnish and Paint Symposium

Speakers at the second New York University Symposium on Varnish and Paint Chemistry, left to right: Prof. J. Happel, A. J. Liebman, Dr. Henry J. Masson, Assistant Dean, Graduate Division, College of Engineering; Dr. M. Kronstein, G. S. Cook, Dr. H. K. Work, Dr. H. F. Payne and Dr. J. Hillier.

Nine Topics Are Given On Technical Program

The second "Symposium on Varnish and Paint Chemistry" of the College of Engineering of New York University, University Heights, New York, was held November 19, 1949. This was the second symposia of this title at the University, the first having been held in November, 1948.

Technical program for the 1949 program was as follows:

Basic Research and Its Application

"The Electron Microscope in Industrial Research," by Dr. James Hillier, Research Laboratories, R.C.A., Princeton, N.J.

"The Gel State in the Formation of Organic Coatings," by Dr. Max Kronstein, Research Associate and Adjunct Professor of Chemical Engineering, New York University, member of NACE TP-6G Committee.

Protective Coatings

"Service Analysis of Surface Preparation and Paint Application Economics," by A. J. Liebman, Dravo Corp., Pittsburgh, Pa., chairman of the Committee on Surface Preparation, National Association of Corrosion Engineers.

"A Determination of Fire Retardant Properties of Paints," by A. W. Van Heuckeroth, R. W. Hill and G. S. Cook, United States Engineer Research and Development Laboratories, Fort Belvoir, Va.

"Emulsion Paints, Theory and Practice," by Dr. Henry F. Payne, American Cyanamid Co., secretary of the American Chemical Society, Division of Paint Varnish and Plastics Chemistry.

Laboratory Demonstrations

"Electrographic Printing Method," (New York University Paint Project. Dr. Kronstein and co-workers).

"The Adherometer," Interchemical Corp., Research Div. Dr. Clifford R. Rollé and Sidney Krakauer.

"Testing Chemical Pretreatments on Metal," (New York University Paint Project).

"Electrical Measurements in Metal-protective Paint Research," National Lead Company Research Laboratories. D. L. Hawke.

Surface Technology Program

The yearly symposia are outgrowths of the developing surface technology program at New York University, which, initiated during the war, was divided into courses on surface finishing for the general public, now given without credit, and the graduate engineering courses for which credit is given toward higher academic degrees.

A practical laboratory course was developed with the cooperation of two New York area varnish and paint industrial organizations which purchased special laboratory equipment necessary.

Scope of the course now includes raw materials, principles and application of organic coatings, practice and evaluation of metal cleaning and metal pretreatment processes and their effect on the life of subsequent coatings.

Papers Are Published

Papers presented at the 1948 symposium have been published by the College of Engineering.

Following are the titles of the papers:

Research and Test Methods

"The Photography of Surface Details of Glossy Surfaces," by Harold R. Luck and R. C. Archibald, Research Laboratory, Shell Development Co., Emeryville, Cal.

"Abstract on an Informal Talk on Infrared Spectroscopy on Polymer Materials," by Dr. G. B. B. M. Sutherland, Professor, Cambridge University, England.

"Application of Infrared Spectroscopy to the Study of Drying Oils and Certain Plastics," by Dr. Max Kronstein, Adjunct Associate Professor of Chemical Engineering, New York University.

Protective Coatings I

"Protective Coatings for Underwater Steel Structures," A. W. Van Heuckeroth, R. W. Hill, G. S. Cook, Materials Branch, Engineer Research and Development Laboratories, Fort Belvoir, Va.

"Fungicidal and Solvent Retention Problems in Organic Film Coatings," by Aubrey J. Raffalovich, U. S. Signal Corps Engineering Laboratories, Fort Monmouth, New Jersey.

Adhesion

"A Study on Some Methods of Measuring Adhesion of Paint Films," by Dr. Charles J. Marsel, Assistant Professor of Chemical Engineering, New York University.

Drying Oils

"Studies on the Systematic Fractionation of Bodied Linseed Oil (Standoil)," by Dr. J. Petit, Assistant Director, French Paint and Varnish Research Laboratories, Belleville, Paris, France.

"Some Additional Facts with Respect to the Formation of Bodied Linseed Oil," by Dr. Max Kronstein.

Protective Coatings II

"Insulating Varnishes and Varnished Products Used as Electrical Insulation," by F. M. Damitz, President, National Varnished Products Corp., Woodbridge, N. J.

Third World Petroleum Congress Sections Set

Ten master sections for organization of technical presentations have been announced for the Third World Petroleum Congress to be held at The Hague—Scheveningen May 28—June 6 1950, inclusive. These sections will discuss papers submitted by petroleum experts of international standing. Discussions and conclusions reached will be published in the Proceedings of the Congress.

The ten sections are: 1—Geology, geophysics, geochemistry; 2—Drilling and oil production. 3—Physical technology. 4—Oil Processes involving chemical conversions. 5—Production of chemicals from petroleum, their properties and applications. 6—Measurement and control, testing, chemical analysis. 7—Utilization of oil products. 8—Construction of equipment, materials, corrosion. 9—Transport, storage, distribution. 10—Economics, statistics, documentation.

Opportunities for those participating in the congress to visit places in The Netherlands and reception and entertainment of ladies attending also are being arranged.

"Photomicrometer" Is Developed by NBS

Determination of the magnitude of lattice strain in a crystalline material whose interatomic spacing is altered by external stress is possible to a high degree of accuracy with a new "Photomicrometer" developed at the National Bureau of Standards. The device is an outgrowth of investigations with x-ray diffraction strain measurements by John A. Bennett of the institute. The apparatus is essentially a densitometer with a dial indicator to measure movement of the film. Results can be reproduced within .01 to .02 mm. A saving of 25 percent of total time or 15 to 20 minutes per pattern is claimed for the device.

8 NACE Members Among Materials Review Authors

Eight NACE members were among the 21 authors collaborating on the "Third Annual Materials of Construction Review" appearing in the October, 1949 issue of *Industrial & Engineering Chemistry*. The authors and topics were as follows:

Ellis D. Verink, Jr., and Robert H. Brown, Aluminum Co. of America—"Aluminum Alloys."

C. Lawrence Bulow, Bridgeport Brass Co.—"Copper, Wrought, and Copper-Base Alloys."

C. P. Larrabee, Carnegie-Illinois Steel Corp.—"Iron, Mild Steels, and Low Alloy Steels."

W. Z. Friend, International Nickel Co.—"Nickel and High Nickel Alloys."

Marshall H. Brown and William B. DeLong, E. I. DuPont de Nemours and Co., Inc.—"Steels, Stainless, and Other Ferrous Alloys."

H. H. Uhlig, Massachusetts Institute of Technology—"Less Common Metals."

Other materials included in the review were carbon and graphite, cements, ceramics, elastomers, fibers, lead and its alloys, plastics, hard rubber, tin and its alloys, and wood.

Attention was given to the corrosion resistance of many of these materials.

Dr. J. W. Ryznar to Head ASME Corrosion Group

Dr. J. W. Ryznar, National Aluminate Corp., and a member of the NACE Editorial Review Committee and active otherwise in the association has been named chairman on the ASME subcommittee on corrosion of the society's Joint Research Committee on Boiler Feedwater Studies at a meeting of the committee held December 2.

Other personnel changes on the committee included: Dr. S. F. Whirl, Duquesne Light Co., chairman; R. W. Seniff, B. & O. Railroad Co., first vice-chairman; Dr. E. P. Partridge, Hall Laboratories, Inc., second vice-chairman. Continued as officers of their respective subcommittees were R. C. Bardwell, C. & O. Railway Co., "Deposits," and W. L. Webb, American Gas & Electric Service Corp., "Steam Contamination."

Metal Powder Analysis Standard Is Published

The Metal Powder Association has released a new standard for the industry designated MPA Standard 7-49T—Tentative Methods for the Determination of the Iron Content of Iron Powder. Procedures for analysis of the powder are explained. The new standard was prepared because ASTM methods of chemical analysis of iron are said to have omitted any direct methods for determination of total iron, metallic iron or iron oxide content. Other standards issued by the association are available on request.

Corrosion Problems

Questions and answers for this heading should be submitted in duplicate if possible, addressed to "CORROSION PROBLEMS", National Association of Corrosion Engineers, 919 Milam Building, Houston 2, Texas. Questions received at the address above above will be sent to E. A. Tice, The International Nickel Co., Inc., N. Y., who is acting editor of the page. All questions will become property of NACE. Questions and replies may or may not be published under this heading and may be answered either by mail directly to the person asking the information, or published under this heading, or both, at the discretion of the editorial staff. Answers to published questions are solicited. Authors of questions will remain anonymous to readers, while authors of answers may remain anonymous if they request it.

No. 36—When using carbon or graphite rod anodes for galvanic protection of underground steel structures or pipelines, is it considered profitable to follow the practice of tamping in coke breeze as backfill? If so, please explain why.

No. 37—What material, or materials, can be used for a tank, pipe-line, pump, and valves to handle 98% sulfuric acid at 150° F., unaerated. Maximum velocity through a three-inch line would be two feet per second.

No. 38—On a gasoline tank farm or terminal, where tank bottoms and underground pipe-lines are cathodically protected by means of rectifiers, what fire hazards exist during loading and unloading of transport trucks, tank cars, or tankers? Should rectifiers be turned off when loading or unloading? Should all lines to docks and loading racks be insulated from lines under protection?

No. 39—In order to melt snow and ice on city streets and bridges, either sodium chloride or calcium chloride is spread by means of automatic equipment conveyed on trucks. Is there an inhibitor which can be added to the salt to reduce corrosion of steel structures which become wetted by the slushy brine? If so, what is the minimum inhibitor concentration which will effectively stop corrosion?

Do You Have A

CORROSION PROBLEM?

If you do you are invited to submit it to the editor of this section for an answer by persons who have met problems similar to yours and have found solutions.

Pipeliners' Short Course At Tulsa Set Feb. 20-23

Widespread demand for practical training in corrosion control for pipeline superintendents, foremen, engineers and inspectors has resulted in plans, announced by the Tulsa Section of NACE, for a 4-day school to be held Feb. 20 through 23 at Tulsa.

According to R. L. Bullock, Interstate Oil Pipe Line Co., the short course will cover pipe coatings, anode and rectifier installations, and pipe-corrosion testing.

Two full days will be devoted to field work at pipeline locations, emphasizing the practical economies to be derived from proper application of proven corrosion-control methods.

Assisting Bullock in planning and direction of the school will be F. E. Pyeatt, Mid-Continent Pipe Line Co., J. C. Sterling, Stanolind Pipe Line Co., I. B. Tietze, Phillips Pipe Line Co., and other leading corrosion men in the Tulsa area.

Three recognized authorities have been secured to conduct the training course: E. P. Doremus, W. E. Huddleston, and Gaines Laster.

W. E. Huddleston, whose 20 years of pipelining includes some 15 years in the study and mitigation of corrosion, is now head of the Huddleston Engineering Co. of Bartlesville.

Gaines Laster, a partner in the Tulsa Pipe Coating Co., has devoted some 16 years to coating operations on major pipe line projects in this country and abroad.

E. P. Doremus of Cathodic Protection Service, Houston, has served the oil industry since 1936 in research engineering as well as the design and installation of cathodic protective systems.

Registration fee of $5.00, including bus transportation to field locations, should be sent to Frank E. McNulty, Thompson Building, Tulsa.

Comments on CORROSION *From the Nation's Daily Newspapers*

CONCRETE PIPE CORROSION COST SET AT $70,000

(Reported in Hammond, Ind., Times.)

Hammond, Ind., Dec. 7—Replacement of 6000 feet of 30-inch concrete sewer which has corroded to the point it has collapsed at several places will cost between $70,000 and $100,000, officials of the city of Hammond, Indiana, estimate. The sewer, installed about 20 years ago, is reported to have deteriorated as the result of the discharge into it of sulfuric acid wastes from a chemical plant.

Sewage service to homes in the area will be affected if the line is shut off. The city attorney is reported to have said there is no law in Hammond preventing the discharge of corrosives into sewers.

FLAME SPRAYING OF PAINT WITHOUT SOLVENT POSSIBLE

(Reported in Business Week, New York City)

December 3, 1949—Antros, A. B., Swedish manufacturer of paint and painting equipment now is offering for license in the United States a painting process involving the application of a coating made of resins, oils and waxes without solvents. The material is melted in a spray gun by a heater then sprayed through flame to the material where it is said to bond immediately. Antros' process, called Antropahl, is the outgrowth of original developments by a German inventor, August Pahl. The process has been used on ships' hulls in northern waters and in 1936 on a bridge at Hufingen, Germany.

CADMIUM PRICES BOLSTERED BY GOVERNMENT BUYING

(From N. Y. Journal of Commerce, Dec. 14, 1949)

Government stockpiling purchases are seen as a principal reason for sustained price levels of cadmium, production of which has exceeded domestic consumption levels. The metal, a by-product of zinc and lead production, amounted to 8,000,000 pounds in 1949.

WATER MAIN REPLACEMENT WICHITA FALLS PROBLEM

(From Wichita Falls, Texas Record News, Nov. 29, 1949)

Wichita Falls, Texas.—Replacement of city water mains is needed in many instances as a result of the corrosion of the inside of mains and the deposit of minerals which has materially reduced the capacity of the pipes. A bond issue is pending to pay for the installation of 62,480 feet of eight-inch main to replace old four and six-inch pipes, a part of 20 miles of new water main installation contemplated.

Carnegie-Illinois Spends Ten Years Developing New Low Carbon Steel

Ten years of work and corrosion-testing by Carnegie-Illinois Steel Corp. have resulted in the manufacture of a low-carbon (up to 3-100 of one percent carbon) stainless steel with the usual 18-8 ratio of chromium and nickel but without columbium or titanium stabilizers. Test samples of the new steel have been boiled in 65 percent nitric acid for 240 hours and 500 hours in copper sulfate and sulfuric acid without intergranular corrosion, according to Paul F. Voigt, Jr., manager of the Stainless Steel Division of Carnegie-Illinois.

The acid tests were made after heat treatment ranging from 1000 to 1625 F.

The tests were said to qualify the material for use in process vessels which must resist corrosion.

Welding tests, the company reports, indicate the new material's performance is equivalent to 18-8 stabilized materials in applications that involve short heating times at elevated temperatures. Impact, tensile and other tests indicate the low-carbon stainless is comparable to higher carbon grades of 18-8 stainless.

AIChE Proposed Code On Heat Transfer Tests Presented at Pittsburgh

A proposed AIChE testing code on heat transfer designed to provide standard directions for conducting and interpreting performance tests of shell-and-tube type heat transfer equipment for comparison with the manufacturers claims, and to aid in securing reliable full-scale test data was presented for discussion by the Committee on Testing Techniques and Equipment Performance Standards at the AIChE December 5 meeting in Pittsburgh, Pa.

The code is limited to sensible heat transfer in shell-and-bare-tube type equipment, except it may be applied to heaters of shell-and-tube construction where saturated steam above atmospheric pressure is the heating medium and where the heat is absorbed as sensible heat. A preliminary outline of the bubble-cap column section of the proposed standard is available to those interested.

Improved Status Claimed For Engineers' Profession

Every state, territory and the District of Columbia has laws regulating the practice of engineer, Dr. John M. Weiss, head of John M. Weiss and Co., consulting engineering firm of New York City, told a special session of the American Institute of Chemical Engineering at its Pittsburgh, Pa., meeting December 4. Dr. Weiss said a poll of AIChE members revealed that of those replying to the poll 50 percent were licensed and that more than 70 percent of the junior members held a state license.

Corrosion Characteristics of Low Carbon Stainless Steel Reported at St. Louis Meet

New data on the effect of stabilizing elements and the corrosion characteristics of the low-carbon austenitic 18-8 alloys were outlined at the November 21 meeting of Greater St. Louis NACE by M. A. Scheil, Director of Metallurgical Research for A. O. Smith Corp., Milwaukee, Wis. Mr. Scheil said that intergranular attack, caused by carbide precipitation, has been one of the major problems of fabricators in seeking a satisfactory product.

Three methods of avoiding harmful carbides were discussed. First was annealing after fabrication to put carbides back into solution. A second method is to employ a stablizing element, such as columbium or titanium in the alloy. This greatly simplifies many problems by allowing stress annealing without fear of harming the corrosion resistance, and eliminating the necessity of a high temperature annealing operation. The third, newest, and probably most important is the use of the extra low carbon alloys.

These new low carbon alloys of austenitic stainless steels, such as Type 304 LC and Type 316 LC, are being specified as .03% maximum carbon instead of the usual .05% to .08% carbon. Tests have been run on these low carbon alloys which indicate the carbon content bears a direct relationship to the amount of carbides that can form.

Because 1500 to 1600°F heating would be the most desirable for stress-relieving operations, specimens were heated to 1600°F, held for two hours, and then cooled to 1000°F in various specified times. The first were cooled in 10 minutes, the sceond in 60 minutes and a third cooled at the rate of 100° per hour to 1000°F.

Low Carbons Are Unaffected

The laboratory corrosion tests indicated that .020% carbon was not affected by any of the three cooling methods. The .03% carbon was satisfactory for the 10 and 60 minute cooling periods, but did show attack at the 100°-per-hour cooling rate. The .05% carbon was satisfactory on the 10 minute cooling rate, but showed "sugaring" (strong intergranular attack) with cooling rates of 60 minutes and above. These samples were tested in a boiling 65% nitric acid solution.

Pitting Failures Are Discussed

Another of the problems that are encountered is the failure of stainless vessels due to pitting. The effect of carbon and molybdenum on the tendency towards pitting was also brought out. After a definition of pitting as "localized breakdown of passivity" figures were given to show the effect of these two elements in this respect.

It has not been recognized generally, Mr. Scheil reported, that precipitation of carbide or sigma phase by heat treatment can cause or accelerate pitting. The speaker's tests with 10% ferric chloride indicated that increased carbon content did increase the tendency of pitting. This, however, can be controlled by proper annealing temperatures in the regular chrome-nickel grades. On Type 316, the carbon content is of considerable importance with .02% to .03% being the most desired. Molybdenum in excess of 2% reduces pitting, but to be most effective, should be combined with relatively low carbon analysis (.03% max. preferred).

In general, temperatures of 1600-1650° F are satisfactory for hot forming or stress relieving Type 347, Type 316 LC. and Type 304 LC. Stress relieving at these temperatures relieved about 75 to 80% of the fabricating stresses, and when when the cooling rate was reasonable, the speaker said, carbides that may be formed are not harmful. Although the 1600° solution of carbides is not as good as the 1950°F. anneal, it does do a job, he asserted.

NACE
NEW MEMBERS
and
ADDRESS CHANGES

NEW MEMBERS

CALIFORNIA

DEGENHART, THURLO E., Mare Island Naval Shipyard, Bldg. 47, Vallejo, California.

HUDSON, GEORGE H. JR., Industrial Electronics & Transformer Co., 8655 South Main, Los Angeles 3, California.

McINTOSH, RUSSELL W., Pittsburgh Coke and Chemical Co., 1204 Russ Building, San Francisco 4, California.

PENDERGAST, HUGH W., 1318 N. Laurel Ave., Los Angeles 48, California.

RALL, RICHARD A. JR., Industrial Electronics & Transformer Co., 8655 South Main, Los Angeles 3, California.

SCHMIDT, JACOB M., Service & Development Laboratory, A. O. Smith Corp., 5753 Smithway (E), Los Angeles 22, California.

TOMPKINS, ALBERT H., JR., Chanslor-Canfield Midway Oil Co., 4549 Produce Plaza West., Los Angeles 11, California.

VOLK, KENNETH Q., 176 N. Highland Ave., Los Angeles 36, California.

WASHINGTON, D. C.

ATKINS, E. L., Operations Research Office., Ft. Leslie J. McNair, Washington 25, D. C.

ILLINOIS

JEKOT, CHESTER M., Lithgow Corp., 333 West 40th Place, Chicago 9, Illinois.

MOYER, GEORGE H., Standard Varnish Works, 2600 Federal St., Chicago 16, Illinois.

INDIANA

ROBERSON, FRANK, Carnegie-Illinois Steel Co., No. 1 North Broadway, Gary, Indiana.

LOUISIANA

AKERBERG, GEORGE E., Metal Goods Corp., 432 Julia St., New Orleans, Louisiana.

MILLS, EARNEST J., Barnsdall Oil Co., Box 103, Benton, Louisiana.

SLAVIK, EDWARD W., Dowell, Inc., 209 Delta Building, New Orleans, Louisiana.

WHITE, ROBERT P., H. C. Price Co., P. O. Box 263, Harvey, Louisiana.

MISSOURI

FISHER, GEORGE A., The International Nickel Co., Inc., St. Louis 1, Missouri.

NEW JERSEY

MENDIZZA, AUGUST, Bell Telephone Laboratories, Murray Hill, New Yersey.

SCOTT, F. L., United Chromium, Inc., One Union, Carteret, New Jersey.

TAYLOR, R. D., Federated Metals Division, American Smelting and Refining Co., 1160 State St., Barber, New Jersey.

NEW YORK

BAILEY, CLARK A., Johns-Manville Sales Corp., 22 E. 40th St., N. Y., New York.

COLLINS, HARRY, Metallizing Engineering Co., Inc., 38-14 30th St., Long Island City, New York.

EICKHOEF, ARNOLD J., National Lead Co., Research Laboratories, 105 York St., Brooklyn, New York.

JELEN, FREDERIC C., Solvay Process Division, Allied Chemical & Dye Corp., Syracuse 1, New York.

KELLOGG, ANDREW, Central New York Power Corp., 300 Erie Blvd., E. Syracuse, New York.

LATTIN, BENTON CALVER, Westchester Lighting Company, 9 South First Ave., Mt. Vernon, New York.

OHIO

PROCTER, BRYANT S. JR., The H. M. Harper Co., 17600 Detroit Ave., Cleveland 7, Ohio.

OKLAHOMA

BROOKS, RICHARD H., JR., Enardo Mfg. Co., 2729 Sand Springs Rd., Tulsa, Oklahoma.

FLETCHER, FREDERIC H., Middle West Coating & Supply, 207-A Daniel Bldg., Tulsa, Oklahoma.

JAMES, JAY R., Cathodic Protection Service, 314 Thompson Bldg., Tulsa, Oklahoma.

PENNSYLVANIA

DIX, E. H. JR., Aluminum Co. of America, Aluminum Research Laboratories, P. O. Box 772, New Kensington, Pennsylvania.

SCHNEIDER, JOHN H., Penna. Salt Mfg. Co., 1000 Widener Bldg., Philadelphia 7, Pennsylvania.

TENNESSEE

LAMBERT, FRANK J., JR., Carbide and Carbon Chemicals Corp., Y-12 Plant, Bldg 9766, Oak Ridge, Tennessee.

TEXAS

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DAVIS, BILLY H., Texas A. & M., Box 1963, College Station, Texas.

KEMPER, E. O., Permian Enterprises, Inc., Box 4132, Odessa, Texas.

McRAE, J. A., A. J. Hunt Contracting Co., P. O. Box 4066, Odessa, Texas.

PITTMAN, JAMES H., JR., Permian Enterprises, Inc., P. O. Box 4132, Odessa, Texas.

WHITLEY, B. J., JR., 7203 Toland, Dallas, Texas.

FOREIGN

BARNARD, KENNETH N., Defence Research Board of Canada, Naval Research Estb., H.M.C.S. "Stadacona," Halifax, Nova Scotia.

HYATT, BAKER, J., Canadian Industries Limited, P. O. Box 10, Montreal, Canada.

SPECTOR, DOV, Schapira Tyroler & Co., Electrical Engineers, 18 Mikve Israel St., Tel-Aviv, Israel.

CHANGES OF ADDRESS

(Old Address Follows New Address in Parenthesis)

CALIFORNIA

EVANS, J. M., Standard Oil Library, P. O. Box 3495, San Francisco 20, California. (225 Bush St., San Francisco, California).

FOX, ARTHUR R., Corrosion Engineering Service, Cathodic Protection Systems, 3405 Piedmont Ave., Oakland, California. (1833 Berryman St., Berkeley 3, California).

GOLDKAMP, CHRIS A., Box 1831, San Diego 12, California. (San Diego Gas & Electric Co., Electric Bldg., San Diego, California).

ILLINOIS

LANE, RUSSELL, W., P. O. Box 232, Urbana, Illinois. (Illinois State Water Survey, Oxford, North Carolina).

YEAZEL, F. C., Pipe Line Service Corp., P. O. Box 218, Franklin Park, Illinois. (P. O. Box 661, Westfield, New Jersey).

KANSAS

BEGOLE, EDGAR RAY, Socony-Vacuum Oil Co., Inc., Pipe Line Dept., Augusta, Kansas. (125 Clark St., Augusta, Kansas).

LOUISIANA

MAYNE, PAUL J., Consulting Engr., Box 293, Opelousas, Louisiana. (Route 4, Box 420E, Opelousas, Louisiana).

MARYLAND

DR. C. F. PRUTTON, "Spotswood" Woodbrook, Baltimore 12, Maryland. (570 Park Ave., New York 21, New York).

MICHIGAN

FELLOWS, CLAIRE H., 10115 Nadine Ave., Huntington Woods, Michigan. (16870 Ashton, Detroit 19, Michigan).

MISSOURI

HEVERLY, L. F., c/o Great Lakes Pipe Line Co., P. O. Drawer 2239, Kansas City 13, Missouri. (Ebasco Services, Inc., 2 Rector St., New York 6, New York).

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RUSSELL, JOHN C., 410 South Princeton, Albuquerque, New Mexico. (809 Hogshead, Albuquerque, New Mexico).

NEW YORK

PAIGE, HENRY, 576 E. 91st St., Brooklyn 12, New York. (Massachusetts Institute of Technology, Corrosion Laboratory, Cambridge 39, Massachusetts).

OHIO

FONTANA, DR., M. G., Chairman, Department of Metallurgy, Ohio State University, Rm. 100, Lord Hall, Columbus 10, Ohio. (Ohio State University, 100 Lord Hall, Dept. of Metallurgy, Columbus 10, Ohio).

FRANEK, JOHN A., 820 Ludlow Ave., Cincinnati 20, Ohio. (425 S. Third St., Wilmington, North Carolina).

OKLAHOMA

MUNNEKE, A. S., Stanolind Pipe Line Co., Shawnee, Oklahoma. (Box 591, Tulsa, Oklahoma).

WHEELER, ROGER M., Pipeline Maintenance Corp., 811 South Boulder, Tulsa, Oklahoma. (2604 E. 24th St., Tulsa, Oklahoma).

PENNSYLVANIA

KAMPS, JULIUS M., Koppers Co., Inc., Chamber Commerce Bldg., Pittsburgh, Pennsylvania. (Wailes Dove Hermiston Dept., 828 Union Commerce Bldg., Cleveland 14, Ohio).

TEXAS

CONROY, JOHN H., 2508 Shakespeare Dr., Houston 5, Texas. (5907 Navigation Blvd., Houston, Texas).

HARRIS, JOHN J., Magnolia Pipe Line Co., P. O. Box 2121, Houston 1, Texas. (P. O. Box 227, Beaumont, Texas).

HUGHES, H. D., American Cast Iron Pipe Co., P. O. Box 1491, Dallas 1, Texas. (R. F. D. 7, Box 331, Dallas 6, Texas).

MURRAY, HERMAN D., Cren-Ray Plastics Products Co., P. O. Box 789, Midland, Texas. (The Texas Company, P. O. Box 1270, Midland, Texas).

NEE, JOHN W., c/o Briner Paint Mfg. Co., Inc., 3713 Agnes St., Corpus Christi, Texas. (Napko Paint & Varnish Works, P. O. Box 9145, Houston, Texas).

POLHAMUS, JOHN R., Plant Supt., Southern Alkali Corp., P. O. Box 4026, Corpus Christi, Texas. (P. O. Box 1341, Corpus Christi, Texas).

RIORDAN, MAURICE A., Rio Engineering Co., 3607 Yoakum, Houston Texas. (2239½ W. Alabama St., Houston 6, Texas).

SANDBERG, JOHN H., 4151 Tuam, Houston 4, Texas. (2039 Alta Vista, Houston 12, Texas).

VIRGINIA

CALVERT, R. C. M., JR., 15 Milford Road, Hilton Village, Virginia. (219 Devin St., Oxford, North Carolina).

WISCONSIN

HAHLER, JOHN J., JR., 3048 A. South 9th St., Milwaukee, Wisconsin. (R. F. D. 4, North Platte, Nebraska).

FOREIGN

SHOOR, ABRAHAM, c/o Vulcan Foundries, Ltd., P. O. Box No. 624, Haifa, Israel. (Palestine Purchasing Service, Inc., 386 Fourth Avenue, New York 16, New York).

HADDAD, IBRAHIM SAMI, Trans Arabian Pipe Line Co., Beirut, Lebanon. (Socony Vaccum Oil Company, 917 First National Bank, Wichita, Kansas).

NACE CALENDAR

GREATER ST. LOUIS SECTION—February 20—O. C. Mudd, Senior Corrosion Engineer, Shell Pipe Line Corp., Houston, Texas, "Protective Coatings."

CLEVELAND SECTION — February 21—C. P. Larrabee, Carnegie-Illinois Steel Corp., "The Effect of Composition of Steels on Corrosion."

HOUSTON SECTION—February 14—"Corrosion Inhibition by Film Formation," by Prof. Norman Hackerman, University of Texas, Austin.

SHREVEPORT SECTION — Regular meeting day is second Thursdays Monthly.

Houston Program Revised

Revised program for meetings of the Houston Section has been issued as follows:

February 14—Corrosion Inhibition by Film Formation. Hackerman.

March 14—Protection of Offshore Drilling Structures. Doremus, et al.

April 11—Gas Condensate Well Corrosion Summary. Waldrip.

Texas A. & M. Students Hear Talks on Corrosion

"Corrosion Engineering Aspects of Interest to Electrical Engineering Students," was the subject of a joint talk by C. E. Thorney and M. A. Judah of Central Office NACE staff at the January 10 meeting of Student Chapter, AIEE, Texas A. & M. College, College Station, Texas.

Mr. Thorney covered the annual cost of corrosion to structures each year, the work being done by NACE and other professional groups to reduce this toll, and emphasized responsibility of younger engineers to design against corrosion. Mr. Judah discussed types of corrosion and preventive measures.

Students attending demonstrated interest in corrosion, one NACE junior member expressed hope to enter this field upon graduation and others inquired about duties of and prospects for young engineers in corrosion work.

German Magazine Now Has New Name, Scope

Beginning with January, 1950, the title of *Archivs fur Metallkunde* (Records on Metallurgy) was changed to *Werkstoffe und Korrosion* (Industrial Materials and Corrosion), a communication from Verlag Chemie, GMBH, Weinheim/Bergstr. und Berlin, publishers, announces.

The publication also has added Dr. Erich Rabald, Mannheim, as co-editor, and the publication's coverage is extended to non-metallic industrial materials. Walter Kohler, Chief Engineer, Berlin, is the other editor.

The monthly magazine has been published since 1946 succeeding the periodical *"Korrosion und Metallschutz"* (1925-45). Each copy will contain an average of 48 pages, and the price will be DM 14 for a quarter year or DM 5 for a single copy, including postage. The publication will give principal attention to the needs of consumers, and production, metallurgy, construction and theoretical aspects will be published only to the extent essential to the understanding of problems raised.

Rhodium-Platinum Alloy Spinnerette Displayed

Among the items displayed by The International Nickel Co., Inc., at the 22nd Exposition of the Chemical Industry, New York City, Nov. 28-Dec. 3 inclusive was a three-inch spinnerette of rhodium-platinum alloy pierced with 3000 barely perceptible holes through which into an acid bath is extruded alkaline viscose solutions which there form continuous rayon or synthetic wool fibers. The high corrosion and erosion resistance of the alloy, a by-product of nickel production, recommends it for this and many other services in corrosive environments. High scrap value and long service life offset the high initial cost of the material.

Eight Sulfur Standard Specimens Available

Eight high-purity standard samples of organic sulfur are available now from National Bureau of Standards, where instructions for ordering may be obtained. The formulae of the samples available are: C_2H_6S, $C_4H_{10}S$, $C_5H_{12}S$, $C_2H_6S_2$, $C_4H_{10}S_2$.

Molecule-High Films of vegetable oil can now be measured by research technicians of Carnegie-Illinois Steel Corp., Pittsburgh, Pa., in an oil test apparatus which is basically a long, narrow tray, filled to overflowing with distilled water. Crossway of the tray are set two strips that dip slightly below the surface of the water and project a little above it. One of the strips is semi-fixed and the other movable along a track graduated linearly. A sample of tin plate whose oil film is to be measured is dipped about five times vertically in the water to insure that the ionic action of the water will collect the oil on its surface. The movable transverse strip then is brought slowly down its track pushing ahead of it the film of oil until the pointer of the hydrofil balance deflects measurably. Deflection of the pointer means the oil has been compressed into a rectangle exactly one molecule thick. The area of the rectangular space is then measured. Tin plate is coated with oil to protect it from rust and facilitate further handling and processing.

NEW PRODUCTS—Materials—Service—Literature

"Otiscoloy," a low alloy high-strength steel which the Jones & Laughlin Steel Corp., 492 Jones & Laughlin Building, Pittsburgh 30, Pa., says has four to six times the corrosion resistance of mild steel of the same thickness, is appreciably more effective in this respect than regular copper bearing steel and thereby permits reduced sections without sacrifice of service life is described in a brochure titled "Transportation Steel, Otiscoloy." Copies of the brochure are available on request. Intended principally for use in the fabrication of transportation units, it is especially recommended for service in corrosive environment, such as coal cars, hoppers, ship cargo holds, smoke stacks and sections of farm, road and excavating equipment. Better paint service life is claimed by reason of the thinner rust layer formed at places where moisture penetrates the coating, thereby reducing flaking.

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Alloyed Metals for resistance to heat, corrosion or abrasion, included solids, case treated and weld coatings with or without heat treatment are described and illustrated in a brochure prepared by the Texas Alloy Products Co., 2110 Quitman St., Houston, Texas. Besides weld coated pump plungers, weld coated rods, sleeves, high alloy sleeves, super case pump liners, there are included charts in which are classified large numbers of materials available as weld coatings.

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High Strength Ceramics for mechanical and electrical uses, including parts of equipment where corrosion, high temperature, friction or galling limit metal service life are described in Technical Bulletin 1049, issued by Landes, Zachary & Peterson, Industrial Ceramics Division, 272 South Santa Fe Drive, Denver 9, Col. The material, made by Coors Porcelain Co., is used for many services where corrosives are handled. The manufacturing process is such tolerance of finished products can be held to one-half thousandth of an inch. Glazed finishes also are available but dimensional control cannot be guaranteed.

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"Vibropot" an instrument for earth resistivity measurements with an accuracy of one percent reading on any point on the scale and range is now being manufactured by Associated Research, Inc., 3758 West Belmont Ave., Chicago 18, Ill. Two models are being made.

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"Rosslyn Metal for Heat Resisting Applications," a pamphlet issued by American Cladmetals Co., Arch St., P.O. Box 544, Carnegie, Pa., gives information about the characteristics of this composite of stainless steel or Inconel and copper. Efficient heat conductivity characteristic of copper, with the resistance to corrosion of the stainless steels are features of the material. The stainless metal is bonded to both sides of the copper core.

Stainless No. 20, an alloy steel fabricated by the Alloy Tube Division, The Carpenter Steel Co., Union, N. J., is being fabricated into flexible hose from one-inch to two and five-eighths inch inside diameter. This corrosion resistant material now is available for installations where a flexible hose is essential. The company also makes flexible hose in Types 304, 316 and 347. Carpenter Stainless No. 10 (Carbon 0.08% max., chromium 16.00%, nickel 18.00%) now is being used for production of cold headed bolts and recessed head screws, cold upset and punched nuts and parts that require severe cold coining and extrusion. Outstanding characteristic of the new material is that it work hardens much slower than conventional 18-8 stainless. Corrosion resistance of the new material is said to be as good as or slightly better than conventional Types 302, 304 and 305. Complete information on physical, cold working properties and other data are available in a bulletin issued by the company's Reading, Pa., office. It can be welded, brazed or soldered satisfactorily. If welded with No. 4-A or No. 308 electrodes, the weld will be very tough, but the final assembly should be heated to 1900 degrees F. and water quenched to eliminate possibility of intergranular corrosion. The material also is available in forging billets, hot rolled bars and forgings, cold drawn and ground bars and wire and wire rods.

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"Thermo-Electric generation of electricity for use on gas transmission lines now is possible through the use of a small volume of gas from the lines." Cathodic Servicing Co., Oklahoma City, which is marketing the device, reports the "Thermo-Electric Generator" has a DC output of 50 watts in various voltage and amperage combinations to match groundbed resistance.

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Minimum Surface resistance of oils used in the preparation of Ensign 318 Pen-a-trate, manufactured by the Ensign Products Co., 3528 East 76 St., Cleveland, Ohio. The material contains no kerosene, and helps prevent rust and corrosion.

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Barco Low Torque swivel pipe joint for slow revolving operations, which recommended for handling many fluids and gases including corrosive acids and alkalis at rotational speeds up to 30 rpm is being manufactured by Barco Manufacturing Co., Dept. 39, 1801 West Winnemac, Chicago 40, Ill.

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Commercially Pure titanium tubing manufactured by the Superior Tube Co., Norristown, Pa., is being offered in sizes ranging from ¾-inch x .049-inch wall down to ⅛-inch x .010 wall. Analysis limits have been fixed tentatively as follows: titanium, 99.5 min; with the following in indicated maximum quantities: iron .15, silicon .15, magnesium .10, manganese .10, nitrogen .15, oxygen .20 and carbon .05. Three standard tempers, annealed, half hard and hard drawn are being offered. Representative mechanical properties of annealed tubing are: ultimate strength, 80,000 psi max; yield strength, 40,000 psi min; elongation in 2-inch, 25 percent min; hardness, Rockwell B, B 95 max. Development of heavier thicknesses is under way and a line of seamless tubing ultimately will be offered. A technical data release is available on request.

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Almet Cold Finished flat wire and precision rolled strip in a variety of cross sections and in a wide variety of corrosion resistant metals are available from Alloy Metal Wire Co., Inc., Prospect Park, Moore Station, Pa. The variety of shapes and sizes simplifies production problems where wire is a component, the company claims. A data sheet is available on request.

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Tube-Turn welding fittings will be manufactured at a Chatham, Ontario plant which is expected to be in production in about three months. The plant will be operated by Tube Turns of Canada, Ltd., a subsidiary of Tube Turns, Inc., Louisville, Ky.

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Amercoat Corporation, successor to Amercoat Division, American Pipe & Construction Co., is a wholly-owned subsidiary of the parent company with home offices at 4809 Firestone Blvd., South Gate, Cal.

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Specialty Coatings Laboratory, 1721 North Water Street, Milwaukee 2, Wis., has developed a removable protective vinyl coating designed to prevent corrosion, scratching or abrasion of metals during production, assembly, shipping or storage. The coating is custom-formulated to meet specific uses such as masking or stop-off lacquers and protective films for polished metals. For the latter use a corrosion-inhibitive composition has been developed to retard underfilm corrosion. It is applicable by spray, brush or dipping, is available clear or in both translucent and opaque colors. A sprayed coating has a coverage of 250 to 300 sq. ft. per gallon per mil thickness. It can be air or force dried, peeled off when desired, or formulated to adhere for permanent protection.

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Dampney Silicone Coating Aluminum, for weather-exposed service at temperatures to 750° F has been added to its line of specialty protective coating by The Dampney Co. of America, Hyde Park, Boston 36, Mass. The silicone coating is formulated to withstand either continuous exposure to heat or intermittent heating and chilling, and all conditions of weather exposure, as well as chemical fume attack. Recommended coverage is 1000 square feet a gallon. Drying time is one-half to three hours.

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Kem-Ban, a copolymer with rubber derivatives added is recommended by the manufacturers, Ace Laboratories, 1614-18 Coutant Ave., Lockwood, Ohio, either as a maintenance paint or in product-painting operation a[illegible] a primer or a final coat. Tests reported by the manufacturer indicate the following corrosive environments had no effect on the finish: (All tests except as noted otherwise, 48 hours continuously) Sodium chloride, 30 percent solution, 800 hours; water submersion, 1000 hours; 5 percent sodium hydroxide, 50 percent sodium hydroxide, 28 percent ammonium, 35 percent hydrochloric acid, 66 percent sulfuric acid; 10 percent acetic acid; 10 percent nitric acid, 95 percent ethyl alcohol, sodium nitrate, ammonium sulfate and ammonium sulfite salts. Further data may be secured from the manufacturer.

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Keyes Tank Company, Salt Lake City, Utah and Casper, Wyoming, and Harold E. Davis, Los Angeles, have been named distributors by T. D. Williamson, pipe line equipment manufacturer of Tulsa, Okla. Davis formerly was with Richfield Oil Co. C. E. Spencer, general manager of the Keyes company formerly was tank superintendent for Stanolind Pipe Line Co. Keyes' operations are being expanded to include complete tank service for all types of industry in Montana, Idaho, Wyoming, Utah, Nevada, Colorado, New Mexico, South Dakota and the western part of Nebraska.

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Murray Tube Bulletin, specification folder of the A. B. Murray Co., Inc., McKeesport, Pa., Elizabeth, N. J. and New York City lists, among other items, pipe size stock in stainless steel tubing from ⅛ to 8, in several analyses.

Vulcalock Process rubber lined tanks are described in Catalog Section 9020 which may be secured from the B. F. Goodrich Co., Akron, O. The catalog describes the characteristics of the corrosion and abrasion-resistant rubber linings applied to large and small containers for a wide variety of chemicals in various concentrations. The recommended services are included in a table. Catalog 9780 covers B. F. Goodrick rubber lined pipe pittings and valves. Lining composition is regulated by the service conditions. The catalog also lists sizes of expansion joints, connectors and valves. Industrial acid gloves are covered in catalog section 9035.

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Steel Castings Chart, presenting in tabular form engineering data on casting steels classified according to tensile strength and lists indicated engineering and design applications, current specifications, typical specifications for tensile strength requirements, specific yield point, elongation, reduction of area, hardness and impact evaluations, endurance limits, modulus of elasticity, machinability and types of heat treatments. This chart is being distributed by the Steel Founders' Society of America, 920 Midland Bldg., Cleveland 15, Ohio.

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John Nooter Boiler Works Co., St. Louis, Mo., has changed its name to Nooter Corporation.

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Ralph M. Westcott Co., 1700 South Main St., Los Angeles, 15, Cal., has changed its name to Water Chemists, Inc.

PERSONALS

Herbert J. Cooper, formerly with Bethlehem Steel Corp., has been appointed assistant to the general manager of the Cooper Alloy Foundry Co., Hillside, N. J.

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W. J. Russell, assistant manager of Dowell, Inc., Tulsa, and **Nelson D. Griswold,** formerly chief engineer for Dowell in Tulsa have been elected to the board of directors of the organization.

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Dearborn Chemical Co., Chicago, has made the following appointments: **C. C. Rausch,** assistant vice-president, named manager of Industrial Department's "No-Ox-Id" rust preventive sales. **J. G. Surchek,** technical adviser and engineer, has been made assistant manager of all production and maintenance "No-Ox-Id" sales. **E. M. Welch,** formerly Dearborn sales representative in Pittsburgh, has joined the Chicago office as manager of sales of water treatment and equipment. **C. S. Silsbee** has been named assistant manager in charge of all national accounts and service for both treatment and "No-Ox-Id." **A. H. Reynolds,** formerly directing chemist of the company's laboratories, has been named director of product development, and will be assisted by **L. O. Gunderson. Dr. Wayne L. Denman** has been named directing chemist of Dearborn laboratories.

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Lawrence B. Richardson has been named director of research of Fairchild Engine and Airplane Corp.

PERSONALS

Theodore W. Olson, corrosion engineer for the National Gas Pipe Line Co. of America, Chicago, a member of NACE and Miss Beth Stockwell were married October 29 in the Danforth All Faiths Chapel, Kansas State College, Manhattan. Mr. Olson is from Beattie, Kan.

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Specialized packing materials for valves, pumps, engines, pipe line and other heat, high-pressure and corrosive service will be handled by Alborg Supply and Equipment Corp., 50 Church St., New York, N. Y. **Alvin A. Bogarding,** formerly with American Car & Foundry Co., is president of the new firm.

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A. S. Munneke, formerly at Tulsa, has been transferred to Shawnee, Okla., by his company, Stanolind Pipe Line Co.

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Charles R. Fox has resigned as president of Carnegie-Illinois Steel Corp., Pittsburgh, Pa., to become president of Kennecott Copper Corp., New York. **Clifford F. Hood,** president of American Steel and Wire Co., Cleveland, has been named to head Carnegie-Illinois in Mr. Fox's place. **Harvey B. Jordan,** vice-president of American Steel & Wire has been elected president of that firm, succeeding Mr. Hood. **James E. Lose** has been named executive vice-president of Carnegie-Illinois.

Thomas G. Cullen, an NACE member, has been appointed Western factory representative by Passonno-Hutcheon Co., Boston and Cleveland, manufacturer of Rust-Sele rust preventive coatings and oils. His territory will include eleven Western states, Alaska and Hawaii. Mr. Cullen's temporary offices are at 249 Ninth St., San Francisco, Cal.

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Harvey T. Kennedy has joined the staff of the petroleum engineering department of Texas A. & M. He formerly was with the Gulf Research and Development Co. and active in the work of Technical Practices Committee No. 1.

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Maurice W. Daugherty, chief of the Cleveland Research Division of Aluminum Co. of America at 2210 Harvard Ave., Cleveland, will be made secretary of Aluminum Research Laboratories, New Kensington, Pa. In his new position he will have some of the administrative functions of the director's office. **Walter E. Sicha** will become chief of the Cleveland Research Division. **Alan M. Montgomery** will be assistant chief, together with G. R. Gardner and H. Y. Hunsicker, made assistants in 1948.

Metal Powder Show Set

The Metal Powder Association will hold its annual show April 25-26 at Book-Cadillac Hotel, Detroit. Further information may be secured from the association, 420 Lexington Ave., New York 17, N. Y.

Corrosion Abstracts

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4. CORROSIVE ENVIRONMENTS

5. PREVENTIVE MEASURES

GENERAL

• Miscellaneous

The Work of the British Corrosion Committee. J. C. Hudson. *Ossature Metallique,* **13,** 487-496 (1948); *J. Iron Steel Inst.* (Abs.), **161,** 167 (1949).

An account of the work of the Committee and the researches which it is conducting.—MA.

The Organization of the Struggle Against Corrosion in Holland. C. A. Lobry de Bruyn. *Metaux et Corrosion,* **23,** No. 279, 255-260 (1948).

An account of the Corrosion research organized in Holland by the Centraal Instituut voor Materiaalonderzoek, and a description of some of the work done. This includes research on (a) the corrosion of conduits by soil, (b) the corrosion of electrical conductors, (c) the atmospheric corrosion of steel structures, and (d) sea-water corrosion.—MA.

The Essentials of a Good Report. Florence E. Wall. *J. Chem. Educ.,* **24,** 129-40 (1947) Mar.

Reports constitute the principal product of any well organized research laboratory and therefore their authors should strive for the three qualities essential in all business communications: clearness, conciseness and emphasis. Prerequisites of a good report are discussed at length under the headings of types, organizations, writing procedure, mechanical makeup and processing. 16 references.—RA.

The Technical Report Bugaboo. W. T. Nichols. *Chem. & Eng. News,* **26,** 602-4 (1948) Mar. 1.

Scientific and technical graduates often are unable to write good reports because they do not thoroughly understand their subjects. Only by teaching them to think at the professional level can they obtain sufficient understanding of the art of research, design or plant operation necessary for writing the kind of report most needed. Purposeful, competent supervisory effort is the sure means for developing men to true professional status. If they are taught to think rigorously and to perform a working art, the ability to write satisfactory technical reports will follow. Long practice in writing may then turn satisfactory reports into excellent reports.—RA.

Speak Your Piece. Douglas G. Nicholson. *Chem & Eng. News,* **26,** 1979 (1948) July 5.

The value of a good paper is often lost through ineffectual presentation. Six fundamental details are suggested for improving the delivery of a well prepared manuscript. 2 references.—RA.

Process for Preserving and Disinfecting. I. G. Farbenindustrie. PB. 60449, Frames 481-2; *Prev. Det. Abs.,* **6,** F 20 (1949).

Halongenated aminophenols, e.g., 4-amino-2 bromophenol, 4-amino-2-chloro-α-naphthol, etc., are in general, more effective preservatives and disinfectants than halogenated phenols. They may be used in aq. soln. in glues, cotton, soaps, pigts., starch, etc., 0.006-0.2% by wt. of the material proving effective.—RPI.

• Bibliographies

Bibliography of the Corrosion of Magnesium and Its Alloys. (Including Cathodic Protection). Published by the Dept. of Mines and Resources (Canada) 29 p. (1949) Jan.

This bibliography was prepared at the request of the Sub-committee on Bibliography and Date Presentation of the Bureau of Mines Industrial Advisory Committee on Magnesium Research. It contains 224 references, and space has been left on each sheet for additions. —ALL.

• Organized Studies

The Economics of Oil-Well Corrosion Control. R. J. Villagrana and W. W. Messick, Standard Oil Co., Calif. Paper before API, Pacific Coast District, Div. of Production, Los Angeles, May 12-13, 1949. *Oil Gas J.,* **48,** No. 11, 58-61+ (1949) July 21.

Discussion of types of well corrosion, stray currents damage, evaluating costs of oil-well corrosion and application of corrosion mitigation methods to oil wells. Illustrations include 5% nickel tubing in which galvanic corrosion is concentrated at breaks in mill-scale coating.—INCO.

The Corrosion of Metals. W. H. J. Vernon. Cantor Lectures to the Royal Society of Arts, 1949. *J. Roy. Soc. Arts,* **97,** 578-610 (1949) July 1.

Economics of corrosion, its nature, electrochemical characteristics, immersed corrosion, promoting and controlling factors, accelerated corrosion tests, atmospheric corrosion, study of surface films, their breakdown and factors influencing them, distribution of corrosion, anaerobic corrosion, underground corrosion are discussed. Methods based on modification of design or procedure, methods based on modification of environment, methods based on modification of metal (increase in purity, or addition of other elements), and methods based on protective coatings for preventive measures are described.—INCO.

Coal Freezeproofing and Corrosion. *Power Generation,* **53,** No. 5, 57-59+ (1949) May.

Discussion consists of following short articles:

"Use of Chloride Salts for Freezeproofing of Coal for Utility Boiler," by F. M. Reiter (Dayton Power & Light Co.).

"This Plant Traces Corrosion to Coal Freezeproofing Chemicals," by W. C. Justice.

"Dow Chemical Takes Own Medicine —No Corrosion."

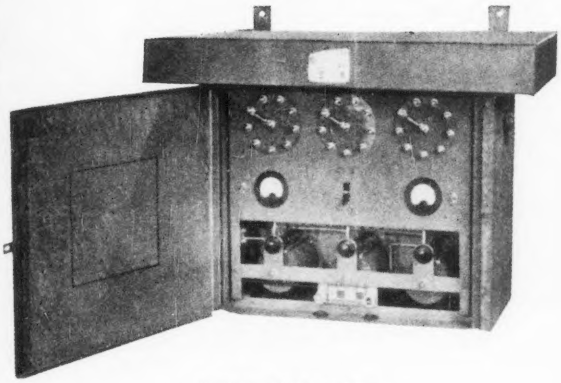
One of the authors sums up available information, shows that there is much evidence on both sides of question, and holds that more careful and authoritative studies by qualified technical committees such as ASME or EEI are needed. Dow Chemical maintains that there is no more corrosion with $CaCl_2$ treated coal in all its handling systems than it had years ago.—INCO.

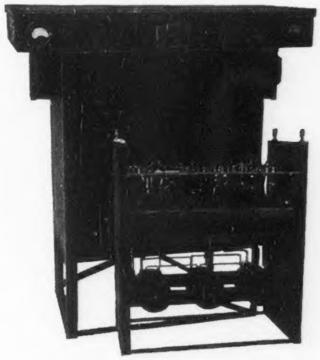
Corrosion of Metals; Microbiological Factors in Underground Corrosion. W. H. J. Vernon. *Chemical Age,* **60,** 355-357 (1949) Mar. 5.

Summary of lecture before meeting of the Royal Society of Arts, London, Feb. 21, 1949.—BLR.

Visits With Some European Corrosion Experts. Pierre Van Rysselberghe. *J. Electrochem. Soc.,* **95,** No. 2, 40C-44C (1949).

Briefly describes the work being carried out by various workers in England, Holland, Belgium, France, Switzerland, Italy, and Germany.—MA.





• Fundamentals

Behavior of Hydrogen in Steel During and After Immersion in Acid. Lawrence S. Darken and Rodney P. Smith. *Corrosion,* **5,** 1-16; discussion, 16 (1949) Jan.

Experiments described are of two principal types, one designed to measure the permeability of steel to hydrogen, the other to measure the saturation concentration and diffusivity of hydrogen in steel, in each case with particular reference to factors associated with the solution in which the steel was immersed. Data are tabulated, graphed, and discussed. Appendix consists of a derivation of an equation for diffusion of hydrogen from a plane surface into steel.—BLR.

Oxygen Overpotential. J. W. Smith. *Sci. Prog.,* **37,** No. 146, 274-283 (1949).

A review of the subject and of the various current theories, including a discussion of the factors on which the value of the overpotential depends. —MA.

Composition and Properties of the Natural Oxide Film on Aluminum. Fred Keller and Junius D. Edwards, Aluminum Co. of America, Research Laboratories, New Kensington, Pa. *Metal Prog.,* **54,** 195-200 (1948) Aug.

X-ray and electron diffraction data show that the natural oxide films on aluminum formed indoors in air are usually amorphous; on extended exposure to weather some hydration may occur. There are several intermediate forms of oxide; of these gamma-alumina is produced by heating the amorphous or one of the hydrated forms to 500-900° C, or even by anodizing at room temperature 100 v or more. Alpha-alumina or corundum is formed only in air at temperatures above 1000° C. Beta-trihydrate is produced when aluminum stands in water up to 70° C, and alpha-monohydrate between 70° and 100° C.

The natural oxide film starts to form as soon as the fresh metallic surface is exposed, probably by the diffusion of aluminum ions to the free surface. In moist air at ordinary temperatures it continues to grow for several days, or even months. Its thickness varies from 10 to 100 Å, and may reach as much as 1000 Å at about 6000° C.

Natural and weathered films are adsorptive, particularly with respect to water vapor. Upon heating, most of the water vapor is liberated below 300° C, hydrogen and small amounts of carbon dioxide coming off at higher temperatures.

Under oxidizing conditions the film tends to remain intact, the reaction rate being low because of the relative insolubility of the oxide in corrosive mediums generally encountered. In fact, aluminum and its oxides are rather stable in weakly acid solutions, but are more readily attacked by strong acidic or alkaline solutions.

The oxide coating formed on high-purity aluminum (99.95%) is continuous, transparent, and is essentially pure Al_2O_3. That formed on less pure material (99.2%) is less continuous and protective due to the numerous oxidation products of alloying elements in solid solution or as intermetallic compounds.

Films formed during thermal treatments are considerably thicker and inherently more corrosion resistant than are normal films.

Old oxide film can be removed mechanically or chemically. The properties of the new film which instantly starts to form are dependent on the method used in the preceding operation. In general, the resistance of the re-formed film is higher when an aqueous medium is employed for removal, and much lower after removal by wire brushing. Films heat-treated in air dissolve more readily than those heated in molten nitrate. —PDA.

Formation of the Natural Oxide Film on Aluminum. Fred Keller and Junius D. Edwards, Aluminum Co. of America, Research Laboratories, New Kensington, Pa. *Metal Prog.,* **54,** 35-41 (1948) July.

The natural oxide film on aluminum begins to form as soon as the metal surface is exposed and reaches a protective thickness within minutes. In dry oxygen the initial rapid growth stops abruptly after 10-40 min., resulting in a film thickness of a few layers of molecules. In the presence of water vapor, growth continues slowly for a substantially longer period. The film thickness in air ranges from 10 to 100 Å. At higher temperatures, especially above 400° C, growth is more rapid and the ultimate thickness considerably greater.

In the presence of water vapor, film growth is attended by the liberation of a small amount of hydrogen peroxide; the effect of this chemical upon a photographic emulsion can be used to follow the reaction. This behavior is known as the Russell effect.

Study of film formation photographically requires the preparation of a series of ten test specimens of 99.95% aluminum and the arrangement of a slot-like holder above the photographic plate. The first specimen is freshly surfaced by abrasion and quickly placed in position 1 in the slot; after 5 min. exposure, the second specimen is abraded and inserted, the first one being pushed to position 2. In this way successive images are obtained, representing the results of a cumulative exposure of ten test pieces which have aged a definite number of minutes from the time of surfacing. After completion of the series, the holder is removed and the plate allowed to age for 24 hr. before developing. The density of the image is measured with a densitometer such as that used for spectrographic work.

PDC Comment: In a later paper by the same authors the composition and properties of these natural oxide films are described. (Composition and Properties of the Natural Oxide Film on Aluminum, *Metal Prog.,* **54,** 195-200 (1948).

The oxidation behavior of aluminum between 200-550°C has also been reported by Earl A. Gulbransen and W. S. Wysong. (Thin Oxide Films on Aluminum) *J. Phys. and Colloid Chem.,* **51,** 1087-1103 (1947).—PDA.

Why Metals Corrode. H. H. Uhlig. *Corrosion,* **5,** No. 6, 169-174 (1949) June.

Survey of mechanism of corrosion: discussion of contact potentials and single electrode potentials; types of corrosion cells; corrosion tendencies of metals; hydrogen overvoltage and depolarization; bacterial action; oxygen concentration; surface corrosion products; corrosion control.—BNF.

TESTING

• General

Aspects of Galvanic Corrosion. International Nickel Co., 1948, 10 pp. Gratis.

Galvanic corrosion may be defined as the accelerated electrochemical corrosion produced when one metal is in electrical contact with another more noble metal, both being immersed in the same corroding medium, called the electrolyte. Factors influencing galvanic corrosion, suggestions to minimize galvanic corrosion, and some practical aspects of galvanic corrosion are presented. The galvanic series of metals and alloys is shown and early studies in the field are noted briefly.

Report on Specimens Removed from Sea Water Tests at Kure Beach, N. C., May, 1948. Report issued July, 1948. International Nickel Co., Inc., New York, N. Y., Development and Research Division.

This study was designed to indicate commercially significant differences in the corrosion of various metals in sea water.

Mild steel, 2% nickel steels, and various other low alloy steels, all with pickled surfaces, were immersed in 3-4 ft. of sea water for 9.7 yr. under conditions devoid of galvanic effects. Insignificant differences both in weight losses and pitting were found among the steels; but these steels, as a class, have some advantage over carbon steel with respect to pitting.

Panels of mild and high tensile steels welded with various electrodes were immersed for 1209 days, and a second identical series for 870 days. All welds satisfactorily resisted corrosion except Murex No. 80 and Fleetweld No. 5 welds on high tensile steel and Unionmelt welds on mild steel. There was no evidence of localized accelerated corrosion along the margins of the austenitic welds.

A mild steel plate was made up with four rows of countersunk rivets including those of SAE 2115 nickel steel, 2% nickel-1% copper steel, carbon steel, and wrought iron. The plate was immersed in sea water for 10 yr. and losses were measured by micrometer calipers. Behavior of nickel or nickel-copper steel rivets in carbon steel plates was much better than those of carbon steel or wrought iron. There was practically no attack on either buton head or countersunk head; corrosion of the carbon steel around the alloy rivets was no greater than elsewhere.

Specimens of a killed carbon steel, two American steels containing 3% and 5% chromium, and two French steels, one containing 2% chromium-1% aluminum and the other 3.7% chromium-1.3% aluminum, were sandblasted; half were either tested in the unpainted condition or were painted with a coal-tar enamel and then immersed. The other half was given a passivating treatment and part of these exposed without paint and the remainder coated with the coal-tar enamel before immersion. One series was removed after 165-days exposure, the other after 351 days. The passivating treatment apparently did not improve corrosion resistance of any sample, but one coat of enamel was beneficial. All low alloy steels corroded similarly, and

Abstract Section Style Outlined

For ease in locating reference data, CORROSION uses a uniform style in its Abstract Section.

The abstracts first are broken down into major classifications of the more common types of corrosion literature. In each review the title of the article is presented in bold face type, followed by the author's name. The publication from which the article was abstracted is printed in italics and is abbreviated in most instances. Following this, in sequence, are the volume (bold face), number in the volume, pages, year and month of publication. In some instances a second reference will be listed in the same manner. This indicates that the article also was published or abstracted in another publication. A brief summary of the article follows the above information and it is concluded with an abbreviation indicating the source of the abstract and contributor. The meanings of these abbreviations usually are listed on the first page of the Abstract Section.

When seeking more detailed data about an abstract, best source of information is the publication in which the article appeared originally. (Listed in italics in the heading.) The contributor of the abstract also may be able to supply additional information. Addresses of most of these publications may be found in the reference section of most public libraries.

all were superior to the killed carbon steel.

In a test to determine the effect of structure on corrosion, panels of killed carbon steel were exposed to sea water for 198 days. Panels which had been heat treated to produce a spheroidized carbide structure corroded almost twice as fast as those with a lamellar pearlite structure. Pitting occurred to the same extent on both.

Samples of several types of nitrided and unnitrided stainless steels were immersed for 178 days. The nitrided steel showed a relatively high-over-all corrosion rate comparable with that of carbon steel. The unnitrited metal was bright but apparently more susceptible to pitting.

Nickel-antimony-lead bearing bronze was almost as resistant as the standard lead-tin alloy when exposed to sea water for 307 days. The nickel-antimony-tin-lead type was inferior to both, corroding more rapidly and being more susceptible to pitting.

Pure hot-rolled zinc samples immersed for periods ranging from 186 to 1460 days corroded at a slightly greater rate than impure specimens.—PDA.

Non-Destructive Testing (Conference). British Iron and Steel Research Association. *Metallurgia,* **39,** No. 230, 111-113 (1948) Dec.; *Foundry Trade J.,* **85,** 558-559 (1948) Dec. 9; *Engineer,* **186,** 552 (1948) Nov. 26.

Reports of a conference organized by BISRA including an introductory lecture by Dr. R. Jackson (BCURA) and papers on radiographic, magnetic and ultrasonic testing, correlation of the methods and radiographic inspection standards.—BNF.

pH—Its Meaning and Determination. I, II. Howard Sanders. *Metal Fin.,* **47,** No. 1, 56-61; No. 2, 58-61, 75 (1949).

I. The significance of pH and the development of the pH scale are described and the colorimetric method of determining pH considered in fair detail. Various types of error, such as indicator error, salt error, protein error, and temp. error, are discussed, and various types of colorimetric equipment mentioned briefly.

II. An account of the electrometric method of determining pH. Hydrogen, calomel, quinhydrone, and glass electrodes are dealt with.—MA.

Tough Materials for Tough Service. Alloy Developed for Condenser Tube and Other Corrosion Resistant Uses Shows Negligible Attack on Welded and Unwelded Samples After 11 Years in Salt Water. *Inco,* **22,** No. 2, 8 (1948) Summer.

Two samples of a 70/30 cupro-nickel alloy, one welded and one unwelded, were immersed in sea water for 11 yr. The welded sample was partly immersed for almost 5 yr. in polluted harbor water at Newport News, Va., then exposed at Kure Beach, N. C., for an additional 6 yr. in sea water flowing at the rate of 120 ft. per min. The unwelded sample was immersed for 11 yr. at Kure Beach. Results were identical for both; the corrosion rate was 0.0002-in. penetration per year. The 70/30 compound also resisted fouling by marine organisms, stress-corrosion cracking, pitting, and erosion, and was not susceptible to dezincification.—PDA.

• Laboratory Methods

Thickness Testing of Electrodeposits. Jet Test for Determining the Thickness of Lead Coatings, and **Review of Methods of Thickness Testing,** by R. A. F. HAMMOND and H. E. EGGINTON, *Electroplating* **1,** 593-599, 609 (1948) Sept.

Seven different methods of testing the thickness of nickel coatings are compared as to nature, accuracy, and ease of application. The adoption of a particular method depends on specific requirements and available equipment. Tests were made on 20-gauge mild steel panels plated with nickel in a Watts-type solution with a current density of 25 amp per sq. ft. The various methods are listed in the order of preference by the author (Egginton).

A specially developed stripping reagent for lead deposits to be used in the B.N.F. Jet Thickness Tester consists of 1 vol. glacial acetic acid, 1 vol. 5% hydrogen peroxide, and 3 vol. distilled water. The strength of the reagent is checked so that 2.5 ml has a titration value of 14.9 ml of 0.1 **N** permanganate.

PDC Comment: A descriptive review by Allen G. Gray of the various methods for measuring the thickness of plated coatings is also on file at the Center. **(Thickness Measurements of Plated Coatings.** *Prod. Fin.* **12,** No. 9, 48-58. (1948) June.—PDA.

Kure Beach Metal Corrosion Tests. E. C. Kreutzberg. *Steel,* **124,** No. 26, 88, 91 (1949) June 27. See also *Marine Eng. Shipping Rev.,* **54,** No. 8, 60-63 (1949) Aug.; and **Marine Corrosion Tests** by G. Weber, *Oil Gas J.,* **48,** No. 12, 236-237, 334 (1949) July 28.

Findings at Kure Beach corroborate existing concepts. Their value lies in fact that they are based upon behavior of test specimens during long exposure to natural sea water and atmosphere. Description of tests carried out at Kure Beach and interpretation of results are given.—INCO.

Fatigue and Corrosion of Sintered and Rolled Titanium. W. L. Williams and W. C. Stewart, U. S. Naval Eng. Exper. Station. *Metal Prog.,* **55,** No. 3, 351-353 (1949) Mar.

Report of corrosion tests to determine behavior of titanium in salt water environments. Tests were conducted in Severn River water to determine the resistance of titanium bar stock, 18-8, and 13 chromium steel to pitting attack and contact corrosion. Photograph shows erosion effects of rotating disks of titanium and cupro-nickel for 60 days at 1140 rpm in sea water at Kure Beach, N. C.—INCO.

Corrosion Tests on Zinc Alloys, With and Without Surface Protection. E. Knobloch and G. Wasserman. I. Behavior Towards Sea-Water. II. Behavior Towards Water-Spray and Atmospheric Conditions. PB. 70039, Frames 6687-706; 6707-20; 6721-39; *Prev. Det. Abs.,* **5,** Met. 141-4 (1948).

Of the many methods of surface protection investigated, chromating, followed by lacquering gave the best results in sea water. On exposure to water vapor this treatment was again found to be most effective. Direct lacquering of the untreated surface was unsatisfactory, but under normal atmospheric conditions corrosion protection was adequate.—RPI.

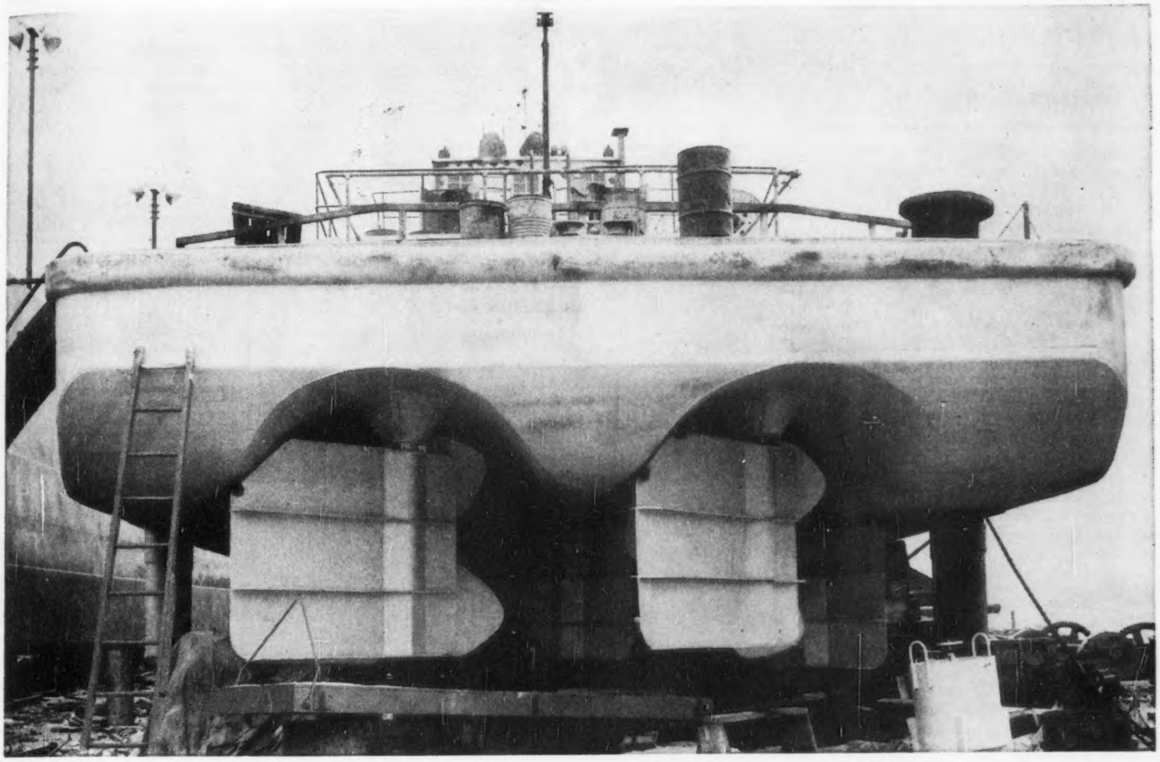
These Tests Help You Get the Right Oil for Industrial Steam Turbines—and Keep It Right. F. C. Linn, Gen. Elec. Co. *Power Generation,* **53,** No. 6, 77-80+ (1949) June.

Discussion includes comparisons of non-inhibited oils with rust- and oxidation-inhibited oils, details of rust and oxidation tests, and how to interpret test results to show remaining life of inhibitors, when to change to new oil and when to add inhibited make-up to prolong life of present oil.—INCO.

Oxidation-Resistance and Some Phase Relationships in the System Chromium-Tantalum-Nickel. O. Kubaschewski and H. Speidel. *J. of the Inst. of Metals,* **75,** 417-430 (1949) Feb.

Describes investigation of the above using thermal, microscopic, and X-ray methods. Gives results of high-temperature oxidation tests on the systems

METHOD	Type	Correction Factor	Percent Mean Variation
A.R.D. magnetic	Nondestructive	zero	7.7
Differential micrometer	Nondestructive	x 0.67	1.5
Differential weighing	Nondestructive	x 0.4	3
B.N.F. Jet Test	Partially destructive	x 1.12	4
Mesle's Chord	Partially destructive	x 0.87	10
Microscope, plastic mounted	Destructive	x 0.82	20
Microscope, plated and plastic mounted	Destructive	x 0.82	15
Micrometer, peeled coat	Destructive	x 0.13– 0.6	8.5



Coro-Gard
BLACK
MINNESOTA MINING & MFG. CO.

nickel-tantalum and chromium-tantalum-nickel. Includes tables, graphs, and micrographs.—BLR.

CORROSION TYPES & INFLUENCING FACTORS

• Factors Biological

Chlorine and Heat Kill Marine Pests. Papers before ASME, Marine Fouling Session, New London, May 2-4, 1949. *Power,* **93,** No. 7, 92-94, 162 (1949) July.

At Kure Beach effects of chlorination were tried out on mussels. Continuous chlorination caused complete kills, and no other live organisms or slime was found in this treated water. In intermittently chlorinated batches, varying numbers averaging 50% were killed and living barnacles and bryozoa were also found. Results show that a definite relationship exists between sea water temperature and killing time. At temperature below 85° F. chlorination shortens killing time markedly. Above this temperature chlorination has no apparent effect. Practical experiences at Lynn, Mass., generating station, and at Redondo station are discussed. Graphs and pictures illustrating results of chlorination and heat are included.—INCO.

Toxicity of Alizarin for Certain Marine Organisms. E. LaGrange. *Compt. Rend. Soc. Biol.,* **140,** 1187-8 (1946); *Prev. Det. Abs.,* **5,** F 28 (1948).

It was found that the toxic effect of alizarin, alizarin sulphonate and purpurin (1,2,4, trihydroxyanthraquinone) varies with the specific organism and with the pH and conc. of the solns.—RPI.

Effect of Illumination and Stage of Tide on the Attachment of Barnacle Cyprids. C. M. Weiss. *Biol. Bull.,* **93,** 240-249 (1947); *Prev. Det. Abs.,* **5,** B 20 (1948).—RPI.

• Factors Chemical

Effect of a Mercurial Fungicide on D. C. Surface Resistance of an Extruded Vinyl Insulated Wire. R. H. Luce and K. N. Mathes. Internat. Engineering Report No. 29; U. S. Air Material Command, Contract No. W 28-099-ac-69; *Prev. Det. Abs.,* **5,** E 40 (1948).

The incorporation of 1% phenylmercuric o-benzoic-sulphimide in an extruded vinyl wire insulation appears effective in inhibiting mould growth and maintaining a high electrical surface resistance.—RPI.

• Factors Physical and Mechanical

Gaseous Corrosion of Welded Samples at High Temperatures. (In Russian) G. N. Kulakova. *Avtogennoe Delo (Welding),* **1947,** No. 4, 23-25.

Losses in weight due to atmospheric corrosion of welded specimens held at 800° C for 100 hrs. were determined. The three types were: aluminum-coated (calorized) steel, a chromium-nickel steel, and a low-carbon steel. Photomicrographs show the structure of the specimens after exposure. Weight loss results are tabulated.—BLR.

The Resistance of Metals to Oxidation at Elevated Temperatures. Benjamin Lustman. Metals Handbook, Amer. Soc. Metals, **1948,** 223-227.

L. examines the factors which govern whether or not a protective oxide film is formed on metals and describes the various methods available for determining resistance to oxidation. The rate of oxidation of a number of alloys, particularly those containing nickel and chromium, is discussed. 29 references are given.—MA.

Why Fret? *Westinghouse Eng.,* **9,** No. 3, 90 (1949) May.

The control surfaces of large mating parts of heavy rotating machines often show unusual patterns of wear, known as fretting corrosion. To determine more accurately how fretting starts and the factors affecting it, a scale model of a large thrust bearing was set up in the Westinghouse Research Laboratories. The threaded "pipes" projecting from the top surface can be tightened or loosened, making it possible to subject the bearing to any type of loading desired. In this manner the motions between various surfaces, which are responsible for the fretting action, can be determined for any distribution of load. Relative motion between the two surfaces is picked up by small gauges and is recorded electrically. Photograph of bearing is shown.—INCO.

Gas Evolution from Supersaturated Liquids. E. C. Marboe, Penna. State College, State College, Pa. Marie Curie Lectures at Penna. State College, April 5, 1949. *Chem. & Eng. News,* **27,** No. 31, 2198-2202 (1949) Aug. 1.

Cavitation and subsequent corrosion of marine propellers as occurring on the Maurentania and Lusitania in 1915, was due to difference in solution between the eutectic and the "mixed crystals" of the manganese bronze alloy from which the propellers were constructed. A propeller was constructed from a manganese bronze alloy which contained as little eutectic as possible and which could better withstand work-hardening from repeated hydraulic blows accompanying the collapse of cavities. This metal was called "turbadium." The chemical effect of the cavitation of water on the destruction of marine propellers is explained. In the ocean the propeller whips the molecule and breaks the chemical bonds, dissociation occurs. The fracture of the water molecule exposes hydrogen and oxygen atoms which are electrically charged or chemically unsaturated. A propeller moving along in a whirling solution of H^+ and OH^- ions is exposed to the simultaneous attack of a strong acid and a strong base. This combined attack leads to strong corrosion. If the water contains dissolved O_2 or potassium iodide, other chemical reactions are possible. Each cavitation exposes a fresh metal surface which in turn recombines with the water to form a new oxide bond. This continued formation and breakage of bonds rapidly corrodes the metal surface.—INCO.

The Dynamics of Cavitation Bubbles. M. S. Plesset, read at the 1948 Annual Meeting of the American Society of Mechanical Engineers; Paper No. 48-A 107.

Three regimes of liquid flow over a body are defined: 1) non-cavitating flow; 2) cavitating flow with a relatively small number of cavitation bubbles in the field of flow; and 3) cavitating flow with a single large cavity about the body. The assumption is made that, for the second regime of flow, the pressure coefficient in the flow field is no different from that in the noncavitating flow. On this basis, the equation of motion for the growth and collapse of a cavitation bubble containing vapor is derived and applied to experimental observations on such bubbles. The limitations of this equation of motion are pointed out, and include the effect of the finite rate of evaporation and condensation, and compressibility of vapor and liquid. A brief discussion of the role of "nuclei" in the liquid in the rate of formation of cavitation bubbles is also given. A distinctive feature of the hydrodynamics of liquids is the possibility of the coexistence of a vapor, or gas phase with the liquid phase. Such two-phase flow is usually called cavitating flow, although it could as well be characterized as liquid flow with boiling. Cavitating flow has great theoretical interest, in addition to the hydrodynamics involved, because of the relation of this flow condition to the physical-chemical properties of the liquid. The practical significance of cavitation is of course clear. The drag of submerged bodies moving through a liquid rises when cavitation appears; similarly, the efficiency of pumps, turbines, and propellers drops with the development of cavitation; and the damage which may be produced by cavitation in these devices is well known.—TIME.

Stress Corrosion in Naval Brass Weldments. B. Ronay, USN Eng. Exp. Station. Paper before AWS, Ann. Mtg., Philadelphia, Oct. 24, 1948. *Welding J.,* **28,** No. 4, 358-363 (1949) Apr.

Discussion of investigation to determine cause of cracks and, in event it is established that crack development is directly attributable to welding procedure employed, to develop preventive methods. Restrained portion of Naval Brass weldments fabricated by arc welding are subject to stress corrosion unless stress relieved. In restrained Naval Brass weldments residual stress of 9000-psi in tension is reached in direction of weld. Preheating alone, even though preheat temperature of 400° F. is used, is insufficient to prevent stress corrosion. Postheat treatment at 750° F. maintained for a period of not less than an hour and a half for each ½ in. of material followed by cooling to 250° F. and at rate of max 150° F. per hour prevents stress corrosion regardless of preheat temperature used in course of fabrication.—INCO.

Fatigue and Corrosion of Sintered and Rolled Titanium. W. Lee Williams and William C. Stewart. *Metal Prog.,* **55,** 351-353 (1949) Mar.

Data reported were obtained on titanium made by the Bureau of Mines in the following forms: sheet 0.0625 in. thick and 6 1/16 in. wide, bar ⅞ in. diam., and wire 0.1265-in. diam. Possible applications are discussed.—BLR.

CORROSIVE ENVIRONMENTS

• General

Corrosion of Galvanized Roofing Iron in Contact with Moist Building Materials, Earth, Clay and Sand. A. V. Solov'ev. (In Russian) *Zh. Prikhladnoi Khimii,* **22,** No. 1, 62-66 (1949) Jan.

Gives results of tests at room temperature on both galvanized and bare iron in 18 materials, including heat insulating materials (silicate, foam, asbestos, asbestos cement, clinkers, etc.), sillimanite, clay, bricks, sand, peat, "black earth," gypsum (plaster), and portland cement containing 9% bituminous paste. A zinc coating 0.02 mm. thick was found to give fair to good protection in some cases.—BNF.

Surface Reactions of Metals; Effect on Wear, Friction, Lubrication and Finishing. G. Tolley. *Metal Ind.,* **75,** No. 4, 68-70 (1949) July 22; *Ibid,* No. 5, 89-91 July 29; *Ibid,* No. 6, 112-113, Aug. 5.

Classification of surface reactions of metals into two groups—physico-chemical and physico-mechanical, and discussion of one example from each group giving the recent concepts and developments in these fields. Discussion includes measurement of surface roughness, measurement of surface area, Bowden and Rideal's method, adsorption method, corrosion, corrosion inhibitors, restrainers, high temperature oxidation, preferential corrosion, friction and lubrication. 26 references.—INCO.

• Atmospheric

Tentative Definitions with Procedures Relating to Conditioning and Weathering. E41-48T. ASTM Book of Standards, Suppl., Pt. 11, 257-9 (1948)—RPI.

Corrosion of Telephone Outside Plant Material. K. G. Compton and A. Mendizza, Bell Telephone Labs. Paper before NACE, St. Louis, Apr. 5-8, 1948. *Corrosion,* **5,** No. 6, 194-197 (1949) Jan.

A broad overall picture of problems resulting from corrosion in telephone outside plant and manner in which they are met and solved by telephone plant engineer. In view of anodic corrosion of lead cable in contact with Monel racks, lead shims are placed between cable and rack to absorb brunt of galvanic attack. Use of a stainless steel is still being studied. Photographs of anchor rods of 27 alloys. 10 references.—INCO.

Corrosion Behavior of Aluminum Alloys. Admiralty Corrosion Committee, Hull and Non-Ferrous Corrosion Sub-Committees. ACSIL/ADM/49/63. Metallurgical Report DMQ. *Journal,* The British Shipbuilding Research Association, **4,** No. 4, Abst. No. 2,609 (1949) April.

A detailed account is given of the first stages of the second part of a comprehensive investigation of the corrosion characteristics of light alloys exposed to half-tide conditions. An abstract of the report on the first part of this investigation was published in Abstract No. 595 (Dec., 1946). In the present series of tests thirteen alloys are being studied. The specimens each consist of two 6-inch x 6-inch plates riveted together through a 1-inch overlap. The aluminum panels are coupled either to similar aluminum panels or to galvanized steel. A painted and an unpainted specimen of each type are being used. The appearance of the specimens after a month's exposure is described in an appendix. The condition of most of the specimens involving aluminum alloys joined together and exposed unpainted is practically unchanged, although there are definite signs of nodular attack on the specimens of AW16, a fully-heat-treated copper-manganese-zinc alloy. Some of the cast panels shows traces of white nodules of corrosion product in the heads and points of the rivets. The condition of the aluminum alloys joined to galvanized steel is excellent, with the exception of the AW16A specimens, which show a slight nodular attack in areas remote from the steel. The galvanized steel panels all have a thin white coating, oxychloride. All the painted specimens are in excellent condition.—TIME.

Atmospheric Corrosion of Metals. G. Schikorr. *Archiv fur Metallkunde,* **2,** No. 7, 223-230 (1948). *Electroplating,* **2,** No. 6, 431 (1949) June.

A review of experiments carried out in Berlin area which confirm published reports for corresponding industrial atmospheres in other parts of world. The corrosion rate was related to the sulfur compounds present.

• Chemicals Inorganic

Oxidation of Turbine Oils in the Laboratory. D. Wyllie and G. C. N. Chessman. *J. of the Inst. of Petro.,* **35,** 61-72 (1949) Jan.

The behavior of typical oils during a standard oxidation test was observed both under standard conditions and using a modified test. The possibility of substituting oxygen for air is considered. Peroxides are not present in more than negligible quantities during oxidation, but the peroxide value rises on conclusion of the oxidation. The oxidation-corrosion test of Pope and Hall was shown to be unsuitable for turbine oils, and the use of interfacial tension as a criterion of the extent of oxidation is not advised. 14 ref.—BLR.

Sulphur in Diesel Fuels; Factors Affecting the Rate of Engine Wear and Fouling. J. J. Broeze and A. Wilson. *Automobile Engineer,* **39,** 118-123 (1949) March.

Describes relevant physicochemical reactions of sulfur in the engine, focusing attention on the trioxide produced during combustion as the principal cause of ill effects. Certain beneficial rules of engine operation (particularly as regards coolant temperature) and design are proposed. Metallurgical expedients such as chromium plating and the use of special additive-type lubricants are emphasized. Instances of the satisfactory use of high-sulfur fuels are given. 14 ref. —BLR.

The Preparation, Properties and Handling of Elementary Fluorine. A. J. Rudge. Paper before Soc. of Chemical Industry, Newcastle Sec., Oct. 20, 1948. *Chem. & Ind.,* No. 16, 247-253 (1949) Apr. 16.

Descriptive review of contributions made to the development of elementary fluorine. In study of anode phenomena, mention is made of use of nickel anodes. Where platinum was formerly considered essential for construction of apparatus used with elementary fluorine, mild steel, nickel, brass, aluminum, magnesium and lead may be used at ordinary temperatures, and in substantial absence of hydrogen fluoride. Fluorine may be metered in a conventional flow-meter using a nickel orifice plate and a fluorine resistant liquid as manometric fluid.—INCO.

Production of Acetic Anhydride. L. W. J. Loveless. *Ind. Chemist,* **25,** No. 293, 325-328 (1949) June.

This paper describes the design of a plant for catalytic cracking of acetic acid to acetic anhydride; results of corrosion tests at 875° C on five high temperature alloys (iron-chromium-nickel, iron-chromium) used as reaction tubes are given on pp. 326-7.—BNF.

An Indirect Aroclor Heater for Unit Chemical Operations. M. McArdle, L. C. Garrett and P. G. Benignus, Monsanto Chem. Co. Paper before ACS, Alabama, Sec., Dec. 8, 1945. *Ind. Eng. Chem.,* **40,** No. 7, 1341-1344 (1949) July.

Discussion of properties of Arochlor 1248, the characteristics of which indicate that it is an ideal liquid phase heat-exchange medium for temperatures up to 300° C. Article illustrates design and operation of heaters used by Monsanto plants. Among tables is one showing resistance of copper, nickel and stainless steel, among other metals, to Arochlor 1248.—INCO.

Action of Refrigerants on Aluminum. *British Refrigeration Association News Sheet,* **2,** No. 4 (1948) Aug.-Sept. *Light Metals Bull.,* **11,** No. 3, 110 (1949) Feb.

As a result of discussions which the association has had with the British Aluminium Co., Ltd., members were asked to note the following.

Methyl chloride reacts with aluminum under certain conditions to form combustible aluminum/methyl chloride compounds. The conditions for the formation of these compounds are difficult to produce, but there is always a possibility of these conditions occurring naturally. Where the aluminum is used for the construction of the refrigerator case, as distinct from the refrigerant circuit, the possibility of reaction between methyl chloride and aluminum is restricted to cases where a liquid leakage occurs. In cases where a stove enamel reasonably resistant to solution by methyl chloride is used the chances of reaction are still further reduced.—ALL.

Titanium and Zirconium Corrosion Studies—Common Mineral Acids. E. A. Gee, L. B. Golden, U. S. Bur. Mines, and W. E. Lusby, Jr., Univ. Md. *Ind. Eng. Chem.,* **41,** No. 8, 1668-1673 (1949) Aug.

Titanium is resistant to sulfuric and hydrochloric acids only at low concentrations but is almost completely resistant to all concentrations of nitric acid. As a corrosion resistant metal in hydrochloric and nitric acids, its general behavior is comparable to Type 316 stainless steel. However, it is somewhat less resistant than latter in sulfuric acid. Zirconium is relatively resistant to all concentrations of hydrochloric, nitric, and phosphoric acids, although it is attacked by high concentrations of sulfuric acid at elevated temperatures.—INCO.

PREVENTIVE MEASURES

• Non-Metallic Coatings

Theoretical and Practical Observations Organic Coatings for Corrosion Protection. G. H. Young. *Metaux et Corrosion,* **23,** No. 278, 232-241 (1948) Oct. (In French).

Theory of high polymers; nature of the film; relationship between constitution and film properties (minimum coating weight, permeability, adhesion, etc.); metal protection and use of pigments. Basic metals were platinum, copper, tin, iron, zinc (galvanized iron), and aluminum.—BNF.

Countering Corrosion. G. H. Young. *Metaux et Corrosion,* No. 278 (1948). *Chim. Peint.,* **12,** No. 1, 14-6 (1949).

A general reveiew of corrosion problems, with particular reference to modern developments in media and pigments for corrosion resistant paints and to the importance of metal surface preparation.—RPI.

Combatting Corrosion with Rubber Lining. R. McFarland. Hills-McCanna Co.; *Corrosion,* **5,** No. 3, 98-99 (1949) Mar.

The use of rubber linings to protect metal surfaces from corrosive attack is discussed. In applying rubber lining for corrosion resistance, the standard commercial practice is to apply a minimum of 1/8 in. to 3/16 in. over the metal surface. Where chemical attack is expected, and in the case of soft rubber linings for combined corrosion and abrasion resistance, the thickness is increased to 1/4 in. minimum. Corrosion-resistanct rubber linings are divided into three physical classes: soft linings, semiflexible linings, and the hard (Ebonite) linings. The semiflexible lining is composed of a thin, soft layer of tie-gum between the metal surface and the thick layer of specially compounded, semiflexible hard-rubber lining. The Ebonite lining contains the highest ratio of rubber hydrocarbons and sulfur, which when cured forms a highly inert, hard chemically-resistant material. The type of lining for an application depends upon the design of the equipment, type of chemical service, temperature, the amount of protection against abrasion resistance combined with corrosion resistance, etc. The proper choice of the rubber lining, especially for certain chemicals at elevated temperatures, will ensure the most efficient material with the longest service life.—TDD.

Anti-Corrosive Paints for Iron and Steel. Trade Literature received from Vinyl Products, Ltd., Butter Hill, Carshalton, Surrey. Jan. 1949.

A zinc dust anti-corrosive primer based on a polystyrene vehicle is described. The dried film contains 96 per cent of zinc and the paint has a coverage of 400 sq. ft. per gallon. This primer is recommended for painting on galvanized iron which is beginning to fail, or on pickled, sandblasted or mill-scaled steel. It should not be applied to rusty surfaces until the rust and loose scale have been removed. When used against sea water, only old paint and loose rust need be removed, though the best results are obtained when the rust is cleaned down to expose bare patches of metal. An iron oxide paint and a decorative top coating, both based on the polystyrene vehicle, are also supplied for application on the zinc dust primer.—ZDA.

Mechanism of Pigmentation of Anti-Corrosive Paints and Varnishes. H. Wagner. *Paint Varn. Prod. Mgr.* **29,** No. 3, 63-70 (1949) Mar.

A review of published information on the anti-rusting properties of pigments. It is suggested that some zinc chromates act by forming a passive oxide film, and in support of this it is claimed that a zinc chromate containing zinc oxide is more effective than ordinary zinc chromate. The efficacy of these chromate pigments is affected by the nature of the vehicle, which is best when it does not tend to reduce the pigment: alkyd resins are better than linseed oils. The action of zinc dust is said to be less than would be expected from electrochemical considerations, and it is suggested that the surface skin of the iron is polarized or that oxide forming on the surface of the zinc particles stifles the action. Other pigments are also discussed in detail.—ZDA.

• Inhibitors

Anti-Corrosive Power of Inhibitors and Molecular Structure. I. Measurement of Some Organic Compounds in an Acid Medium. II. Measurements on Derivatives of Thiourea and Isothiocyanates. L. Cavallaro and G. Bolognesi. *Atti Acad. Sci. Ferrara,* 24, No. 1, 10 pp., No. 2, 6 pp. 1946-47); C.A. **43,** 547-8 (1949) Jan. 25.

Tests with soft steel in hydrochloric acid were conducted with and without the use of inhibitors. The inhibitors used were: potassium cyanide, urea, phenylurea, diphenylurea, ammonium thiocyanate, thiourea, phenylthiourea, diphenylthio urea, allyl alcohol, allylthiourea, pyridine, phenylpyridylthiourea, allylpyridylthiourea, and allylisothiocyanate. The majority of the inhibitors exerted a mixed anodic and cathodic effect. High efficiency was achieved with some inhibitors of low molecular weight. In a few instances a residual effect was noticed after the acid and inhibitor had been removed and was replaced by acid alone. Sulfuric acid was substituted for hydrochloric using methyl-isobutyl, phenyl, and ∝ -naphthyl isothiocyanates, phenylthiourea, both diphenylthioureas, and ∝ -and β -naphthylthioureas. It was found that the inhibitory power is better in the case of molecular asymmetry. There was a resemblance in the behavior of the diphenylthiourea with the two phenyl groups attached to the same nitrogen and the ∝ -naphthylthiourea. A difference in behavior existed in between the ∝ -and β -naphthylthiourea that could not be readily interpreted. There was marked inhibitory power with the thiourea derivatives at concentrations as low as 0.00001M; at higher concentrations the compounds behave as cathodic inhibitors.

Contribution to the Study of the Measurement and Mechanism of Action of Corrosion Inhibitors. Leo Cavallero. *Metaux et Corrosion,* **23,** Nos. 275/276, 184-190 (1948).

A review of corrosion inhibition, mainly with reference to the corrosion of ferrous materials. The molecular structures of inhibitors are correlated with their protective action. The mechanism of inhibition in acid and neutral media is considered. Published information is supplemented by the results of tests carried out by C. A. bibliography of 57 references is given.—MA.

The Reaction Mechanism of Some Organic and Inorganic Inhibitors in a Neutral Medium. L. Cavallaro and A. Indelli. *Atti Acad. Sci. Ferrara,* **24,** No. 2, 11 pp. (1946-47); *C.A.,* **43,** 548 (1949) Jan. 25.

In an electrolytic cell tests using various inorganic and organic inhibitors and also some of mixed character (glycero-phosphates of sodium and calcium) in 5% concentration indicated that it

was not necessary for a substance to form insoluble compound with the products of corrosion to give an anodic inhibitor. It is believed that it is a complicated chemical process that causes inhibition. In most cases under test there was mixed action at both the anode and the cathode. Arsenates of sodium and lead proved to be good inhibitors in an acid medium.

Vapor Phase Inhibitor. *Chem. Eng.*, **56**, No. 3, 182, 184 (1949) Mar.

By application of VPI, developed by Shell Development Co., to papers of Angier Corp. a new and complete rust-preventive-packaging method is made possible. VPI vapor forms an invisible protective film around steel article that prevents corrosion. VPI Wrap need not be in direct contact with steel surface to prevent corrosion. It is recommended for protective packaging of articles made of bare steel or aluminum, and for protection of steel stock in temporary storage between processing steps, and for protection of stored machine or hand tools.—INCO.

• Surface Treatment

Some Principles of Electrolytic Cleaning and Their Application to H. M. Ships. Admiralty Corrosion Committee, Hull Corrosion Sub-Committee, ACSIL/ADM/48/771. *J. Brit. Shipbuilding Res. Assoc.*, **3**, 517, 518 (1948) Nov. *J. Iron Steel Inst.*, **161**, Pt. 3, 264 (1949) Mar.

Instructions are given for the cathodic cleaning and derusting of steel articles, using sea water as the electrolyte, on a scale suitable for service requirements.—INCO.

Phosphate Coating of Aluminum and Polymorphism of Chromium Phosphate. G. L. Clark and A. P. Tai, Illinois University. *Science*, 107, 505 (1948) May.

X-ray diffraction analysis with chromium Kα radiation was used to identify compounds in a light green protective coating produced by treating the surface of aluminum with a chromic acid-phosphate solution.

Most of the lines correspond to those of pure aluminum phosphate prepared from aluminum chloride and phosphoric acid. Additional lines correspond to aluminum oxide and aluminum fluoride, but the chromium phosphate producing the green color is evidently amorphous. In an effort to verify this, an intensive study of chromium phosphates disclosed 1) a dimorphism of the hexahydrate, 2) the identity in crystal structure of the tetrahydrate with the hexahydrate, indicating that two of the six water molecules in the violet crystal must be zeolite, and 3) the amorphous nature of the compounds below the tetrahydrate. This behavior, together with changes on heating, indicate the presence of green chromium phosphate dihydrate in the protective coating on aluminum.—PDA.

Banox. *Corrosion*, **4**, No. 11, 15-16 (1948) Nov.

Banox, an amorphous metaphosphate compound which inhibits rusts and helps lubricate wire in process permits increase in speed of drawing fine high-carbon wire. It was used as a rustproofing and paint-bonding coating prior to painting by manufacturers of household appliances, metal furniture and automotive bodies and parts. Manufactured by Calgon, Inc.—INCO.

Preparation of Metal Surfaces Preparatory to Finishing. V. M. Darsey. *Paint Varn. Prod. Mgr.* (U.S.A.), **29**, No. 3, 78-82 (1949) Mar.

A survey of general metal cleaning and finishing techniques and notes on the preparation of various metals and their alloys. In the section on zinc and zinc alloys, attention is drawn to the application of a phosphate as a basis for organic finishes. The phosphate treatment improves the adhesion of the applied finish to a marked degree. Notes on the finishing of aluminum and its alloys are included.—ZDA.

Use of Flame Cleaning in Painting Gas-Holders. Anon. *Gas Times* (1948) Oct. 8; *ZD.A Abs.*, **6**, No. 11, 171 (1948).

The technique used for rust removal, prior to the repainting of a gas-holder, is described. Flame cleaning was highly successful and the surface uncovered could be painted. The pigments suitable for anti-corrosive paints are discussed. Zinc chromate is accepted as an efficient pigment provided the primer is correctly formulated.—MA.

The Cleaning of Metals. R. Groves. *Metallurgia*, **37**, 40-42, 100-102, 147-149 (1947) Nov.; (1948) Jan.

Part I. Choice of process and cleaning agent.

Three main factors to be considered in cleaning metals are material used, method involved, and machines employed for the process. Choice of a cleaning material is determined by the condition of pieces to be cleaned, by the kind and degree of tenacity of foreign matter to be removed, by the extent to which the surfaces must be cleaned, and by the type of metal. The cleaning process itself will be affected by the form, dimensions, and mechanical strength of the pieces. Choice of machine will be governed by the rate of output per working hour, type of finish or other additional treatment, available room, equipment for bringing cleaning solutions to correct temperatures, and location of the operation in the production sequence. Costs of various cleaning agents, processes, and apparatus are additional important factors.

Types of dirt fall into four main categories: solid dirt, oil film, solid dirt held by oil and grease, and colloids absorbed by dirt. Often a cleaning process or compound effective against one of these will be useless against another.

The degree of adhesion usually determines whether the cleaning material is to be an alkaline, acid, solvent, petroleum, or emulsifying agent. The intended use of the component part determines the degree of cleanliness required. The kind of metal also affects the selection of a cleaner; brass, zinc, and aluminum, for example, cannot be cleaned with a strong alkali but require a noncorroding or nontarnishing emulsifier. In alkaline cleansers the choice of the alkaline salt determines whether or not the degree of alkalinity due to buffer action remains at the desired level.

Part II. Alkaline cleaners.

Although certain of the more active metals require special cleaning compounds, alkalies probably have the widest range of application. Of these the most economical is caustic soda. A simple alkaline salt alone will not remove grease, fat, or mineral oil, but a wetting agent and a soap in colloidal state must be added.

Cleaners for specific operations are listed under four general headings:

1. Deep drawn parts—usually more than one operation is required. An emulsifiable cleaner for intermediate washing is followed by a final alkaline spray.

2. Machine parts—A noncaustic alkaline cleaner similar to that employed on drawn and stamped parts is used except for tallow—emery polished steel where an emulsifiable cleaner is more effective. Special alkaline cleaners are available for machined, buffed, or polished aluminum, aluminum alloys, and zinc parts.

3. Die castings—The method employed depends upon the type of dye casting. With aluminum, magnesium, or zinc allows an emulsifiable cleaner should be used. Parts are usually sprayed with a solution of 1 part cleaner in 10 parts paraffin or other safe solvent, drained, and then rinsed with cold water. If they are to be electroplated, the castings are given an additional 30-second wash with a special alkaline cleaner designed for soft metals, rinsed in water, and then dipped in 1% hydrochloric acid. Alternative methods involve washing or electrolytic cleaning in an alkaline solvent.

4. Oil quenched parts—A heavy duty alkaline solution with comparatively high alkalinity and the properties of soap is used. Protracted boiling in this solution is followed by a boiling, soaking rinse. Such metals as aluminum, zinc, and magnesium require special emulsifiable cleaners.

Part III. Further operations.

Buffed and polished parts to be electroplated require a two-step cleaning operation. An emulsifiable cleaner first eliminates grease, soot, oil, paints, and abrasive material. This is followed by electrolytic processing which seals pores and crevices and chemically cleans the material. The precleaning operation is applicable to any metal.

Steel parts to be used in dipping or in washing machine finish require a high-quality alkaline solution. Parts of nonferrous metals need specially compounded cleaners, the composition being determined by the type of metal. The final operation, i.e., anodic cleaning, requires a solution capable of carrying adequate current to produce a high current density, and, in addition, must be free of ingredients which foster anodic corrosion. The solution must also have good penetrating, wetting, and dispersing properties.

Chlorinated solvents are useful in removing oil and grease from small metal parts having rolled edges, recesses, and pockets which are difficult to drain and dry. They are advantageous for nonferrous metals tending to tarnish when treated with aqueous solutions and rinses. Ferrous metal, however, rusts quickly after treatment, and aluminum decomposes the solvent because of the catalytic action set up by extremely small metal particles on the surface. The usual solvent, trichloroethylene, currently is being replaced with perchlorethylene, a compound having similar properties but requiring no precooling.

Petroleum distillates are used for various forms of industrial cleaning which do not require a physically or chemically clean surface but only elimination of easily removed substances, such as dust and thin oil films.—PDA.

Phosphate Coatings—Developments in Wire, Tube and Deep Drawing Applications. H. A. Holden and S. J. Soouse. Paper before Sheet & Strip Metal User's Tech. Assn. Ann. Gen'l Mtg. and Winter Conf. *Auto. Eng.*, **39**, No. 612, 107-113 (1949) Mar. *Sheet Metal Ind.*, **26**, No. 261, 123-134+ (1949) Jan.

Discussion of the use of phosphate treatment of iron and steel, now used for corrosion protection, for cold working of metals. Procedure for forming a phosphate coating on iron or steel surfaces to assist cold working is fundamentally the same as that used for corrosion protection. Advantages of phosphating for cold drawing include time savings, smooth surface, corrosion resistanec, surface finishing and savings in metal. Typical applications are for wet and dry ferrous wire drawing, tube drawing, deep drawing and the cold pressing and extrusion of steel. Illustrations are given. 14 References.

The Commercial Possibilities of Sherardizing. Anon. *Ind. Fin.* 462-7 (1949) Mar.

A general account of Sherardizing and of the applications of Sherardizing coatings on iron and steel. Though the patents expired some years ago, it is stated that only one company and a subsidiary are now doing general Sherardizing for the trade in Great Britain, and the present article describes the process as carried out by them. Emphasis is laid on the organization of the works, which ensures that the maximum use is made of all equipment by continuous operation. It is pointed out that Sherardizing cannot be expected to give such prolonged protection to steel used in industrial atmospheres as do the heavier zinc coatings applied by hot dip galvanizing; nevertheless, there are many circumstances in which it is a very valuable means of protection. Some notes on Sherardizing costs are included.—ZDA.

Metal Cleaning Methods. Anon. *Ind. Fin.* 438-41 (1949) Feb.

Brief descriptions of metal cleaning methods are given. Those considered are: alkaline cleaning; solvent cleaning; emulsion cleaning; petroleum spirit cleaning; acid pickling; electrolytic cleaning; and mechanical cleaning. There is also a short section on the importance of rinsing after most of the cleaning operations.—ZDA.

Evaluation of Polishes for Use on Aluminum Aircraft Surfaces. R. A. Machlowitz. *ASTM Bull.* (U.S.A.), No. 156, 46-49 (1949) Jan.

The work reported in this paper was performed in the course of preparing a specification covering procurement of aluminum polishes for use on naval aircraft. The following test methods were employed: caking number, nonflammability, flash point, low temperature stability, corrosiveness, abrasive number, coarse particles determination, and measurement of performance properties. Results of tests on eleven selected polishes are given in table form. The test methods are described and their salient features are discussed.—ALL.

Methods and Types of Cleaners for Various Metals. Mat. & Meth., **29**, No. 1, 89-91 (1949) Jan.

Tables listing application of various cleaning agents in power washers, still and soak tanks and electrolytic cleaners for steel, cast iron, zinc-base die-castings, aluminum, copper, brass, and prior to Bonderizing.—BNF.

Anodizing of Aluminum Alloys: Engineering Data Sheet. *Met. Fin.*, **46**, No. 12, 83 (1948) Dec.

A data sheet giving operating conditions, advantages, disadvantages, etc., for processes using sulphuric, chromic, oxalic, phosphoric, sulphamic and boric acids respectively.—BNF.

Oberflachenschutz von Zink und Zinklegierungen. (Protective Surface Treatments for Zinc and Zinc Alloys). *Metalloberflache* (Germany). **1,** No. 9, 220-1 (1947) Sept. (In German).

A concise review of the chemical dips and anodic treatments available for increasing the corrosion resistance of zinc and zinc alloy surfaces. The simple chromate dips are useful, but the finish has a poor resistance to abrasion or washing, and the color is too variable to be of value for decorative purposes. The anodically produced films are considerably thicker, and have the property of absorbing oils and waxes to produce attractive grey or black finishes suitable for indoor exposure. They also may be dyed. Some solution formulae and operating conditions are given.—ZDA.

Contribution to the Study of Electrolytic Polishing of Metals. R. Piontelli, D. Porta, and L. Arduini. *Met. Ital.,* **39,** No. 1, 15-23 (1947).—MA.

Glossary of Polishing Terms. *Prod. Fin.* (Lond.), **1,** No. 8, 33-35+ (1948).

Technical appendix to the interim report of the Costings Committee of the Electrodepositors' Technical Society and the Institute of Cost and Works Accountants.—MA.

Vapour Blasting: Its Many Uses Increase Almost Daily. *Prod. Fin.,* **2,** No. 1, 14-19, 61 (1949).

In this process, a blast of water and fine abrasive mixture is directed against the surface to be treated by means of compressed air. The abrasive media include a specially selected crypto-crystalline chalcedonic silica, pumice, kieselguhr, or even the ground husks of cereals, walnut shells, or other organic solids. The particle size may vary from 80-2500 mesh, according to the class of work. A flotation medium and/or rust inhibitor may be added to the water, and compressed air pressures of 80-120 lb./in.^{2} are used. The advantages and applications of the process are discussed at length. The latter include the cleaning of aluminum and magnesium alloy sand castings, the preparation of aluminum for anodizing, the surface finishing of the moulds for zinc alloy die-castings, and the finishing of automotive and aero-engine parts for improved lubrication surfaces and burr removal.—MA.

Barrel Finishing of Metal Products. XXVI. Barrel Finishing and Its Relation to the Stability of Electrodeposited Surfaces. H. Leroy Beaver. *Prod. Fin.,* **13,** No. 3, 38+ (1948).

It is pointed out that whatever the cause of porosity in electrodeposits, it cannot be claimed that it can be in any way attributed to any barrel-finishing operation. The reverse is in fact the case, since the pressure developed within the burnishing mass work-hardens the plated surface and tends to close the pores, thus at the same time increasing resistance to wear and corrosion. To take full advantage of these effects of barrelling it is necessary to use high-pressure barrels with heavy loads and at low speeds. The salt-spray test clearly distinguishes between parts treated in this way and those barrelled at low pressure and high speed. The use of a sharp burnishing material in barrels before plating is a further cause of instability in the subsequent coating, and the use, as far as possible, of soft, rounded burnishing materials is recommended.—MA.

Barrel Finishing. I. Anon. *Prod. Fin.,* **2,** No. 2, 20-4 (1949) Feb.

This introductory article traces the history of barrel finishing in the U.K. and gives a general description of the process. As a practical art rather than a scientific production process, the technical skill acquired is the result of hard-won experience, and those who "know how" are naturally reluctant to make their knowledge freely available.—ZDA.

Technical Progress in Metal Finishing During 1948. Walter A. Raymond. *Metal Fin.,* **47,** No. 1, 44-53, 99 (1949).

Reviews contributions to metal-finishing theory and to practical electroplating and allied processes in the following fields: polishing, buffing, chemical and electrochemical polishing, cleaning and pickling, wetting agents, stripping and bright dipping, plating, bath-purification methods, surface treatments, solution control, testing of deposits, and special corrosion-preventive methods.—MA.

Magnesium Alloy Protection by Selenious Acid-Dichromate Solutions. L. Whitby. *Metallurgia,* **39,** No. 233, 233-240 (1949) Mar. *Mat. and Meth.,* **29,** No. 6, 89 (1949) June.

Discussion of results of an investigation into influence of sodium-dichromate additions to selenious acid bath includes influence of selenious acid/dichromate ratio and temperature, influence of time and temperature, operational and storage life of bath, dimensional change of specimens and thickness of coating, electrolytic treatment, composition of coating, influence of selenium-dichromate treatment on fatigue endurance limit and use of selenium-dichromate coatings as paint bases. With DTD 120-A alloy selenium-dichromate immersion treatment produces coatings which are more resistant to salt-spray attack and more effective as bases for paint than either selenium coatings or chromate coatings produced by bath of DTD 911. Operational life of solutions is exceptionally long, coatings are free from odor and with one alloy tested, treatment has but little effect upon its fatigue endurance limit. Compositions of coatings consists largely of selenium but some chromium, probably as sparingly-soluble chromate, is also present and may account for marked difference in properties of these coatings compared with those of selenium coatings. Photomicrographs are shown.—INCO.

Immersion Gas Tube Process of Descaling Bar Steel. G. D. Muschlitz. *Iron Steel Eng.,* **25,** 80-83 (1948) Nov.; discussion, 84-86.

Second of two articles on descaling of stainless steel describes and illustrates process used at Midvale Co., Philadelphia.—BLR.

Sodium Hydroxide Descaling of Stainless and Clad Steels. John S. Morris. *Iron Steel Eng.,* **25,** 71-79 (1948) Nov.; discussion, 84-86.

First of two articles on descaling of stainless steel describes and illustrates new process and equipment recently installed by Lukens Steel Co., Coatesville, Pa.—BLR.

Molten Salt Descaling by the Efco-Virgo Process. J. A. Monks and J. McMullen. *Metallurgia,* **38,** No. 228, 311-314 (1948) Oct.

Describes a descaling process (applicable to both ferrous and non-ferrous materials) of which the chief feature is the chemical and physical modification of the scale by the action of molten salts at a temperature of 480-540° C. The scale, so modified, then is removed by a cold water quench followed, where necessary, by a short immersion in warm dilute acid. Originally developed for descaling stainless steels, the process is being increasingly applied to both ferrous and non-ferrous alloys, especially where metal wastage in pickling is a serious item.

Rust Removers and Preventives. *Mining J.,* **230,** 5887, 454 (1948) June 19.

A solution that removes rust, prevents its recurrence and gives key surface for paint, enamel, plating, etc., and keying solution for aluminum which will remove oxidation, prevent it from recurring and act as a binding agent between aluminum and paint are manufactured by Jenolite, Ltd. Alloy tubes containing copper, nickel and iron are resistant to corrosion and erosion by sea water. Aluminum brass tubes are resistant to corrosion and retain their strength to a marked degree at elevated temperatures in region of 400° C. Manufactured by Imperial Chemical Industries, Ltd.—INCO.

Finishes for Machine Parts. J. Mazia, American Chemical Paint Co. *Mach. Des.,* **20,** No. 10, 125-128 (1948) Oct.

Discussion of finishes to metal surfaces as means of corrosion protection, factors influencing choice of finish and brief outline of general categories of finishes. No matter what kind of finish is chosen precleaning is important.—INCO.

Paste for Removing Rust. Mason. *Verniciatura e Decorazione,* **3,** No. 5, 2 (1948).

A paste composed of phosphuric acid 2 (pts by wat.), oxalic acid 2, glycerol 1 and SiO_2 5 is spread on the rusty iron article and left for 20 minutes. It is then washed off with water, leaving the metal perfectly free from rust.—RPI.

The Mechanisms of Some Elementary Surface Reactions. Keith J. Laidler. Proceedings of the Pittsburgh International Conference on Surface Reactions, 51-59 (1948).

A theoretical discussion of the mechanism of some single-stage surface reactions, with some experimental results on the production and recombination of hydrogen atoms on tungsten.—MA.

The Cleaning and Polishing of Small (Metal) Parts in Drums and Bells. Hugo Krause. *Metalloberflache,* **1,** No. 2, 35-38; No. 6, 152; No. 7, 169-171 (1947).

The construction and operation of equipment for the cleaning and polishing of small parts by tumbling in drums and open-ended vessels are illustrated and described. Special reference is made to the high polish which can be obtained by the ball-polishing process in which the articles, together with steel balls, are rumbled in a suitable polishing medium.—MA

Electrolytic Process Removes Corrosion Products. *Intern. Ind.,* **29,** No. 1, 25 (1948) Jan.

The general principle of electroplating in reverse is used in a new process for removing rust and other oxidation prod-

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ucts from corroded metals in Coventry. No sound metal is attacked, so that there is no reduction in dimensions of articles treated. An additional application is removal of sand from intricate castings and a further field of development is in pretreatment of steel parts before painting or cellulosing to secure maximum adhesion. Experiments in developing the process by the British Ministry of Supplies for salvage machine tools finally succeeded and companies have been formed to develop process in Scotland, Canada, and South Africa, with licenses issued to French subsidiary and negotiations for India and Australia. British firm is Modern Machine Tools, Ltd.—INCO.

The Effect of Shot-Peening Upon the Corrosion-Fatigue of a High-Carbon Steel. A. J. Gould and U. R. Evans. *J. Iron Steel Inst.*, **160**, 164-168 (1948) Oct.

Steel peened in seven differnet ways was subjected to corrosion-fatigue in very dilute sulfuric acid and in sea water; fine-ground unpeened steel also was tested. It was found that peening greatly increased the endurance at common stress ranges. Addition of sodium carbonate and sodium bicarbonate to sodium chloride diminished the endurance of peened specimens; at high alkali contents, peened specimens have a shorter life than finely ground specimens.—BLR.

Pickling by Acids and by Sodium Hydride. *Electroplating and Met. Fin.*, **1**, 724-731 (1948) Nov.

Reports on papers by W. F. Bews and by N. L. Evans, respectively, on the above pickling methods, presented to Electrodepositors Technical Society, London, Sept. 20, 1948. Includes discussion.

Metal Cleaning. T. C. Du Mond. *Mat. & Meth.*, **28**, 83-94 (1948) Nov.

Materials & Methods manual gives details of metal cleaning methods and the cleaning of specific metals.—BLR.

Protective Coating for Aluminum. *Die Casting*, **6**, No. 11, 53 (1948) Nov.

A new surface treating chemical called "Alodine" has been developed which can produce a protective coating in two minutes or less and is applied by dipping, spraying, or brushing the aluminum parts.—INCO.

Barrel Burnishing Methods (for Die-Castings). *Die Casting*, **6**, No. 6, 64-67 (1948).

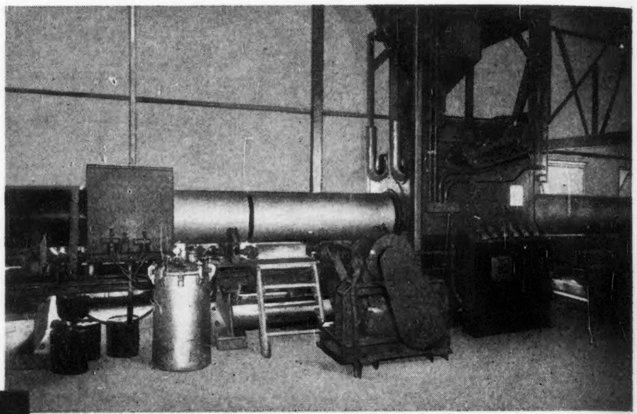
Materials, methods and case histories in the production of high-lustre finishes on small die-castings are discussed.—MA.

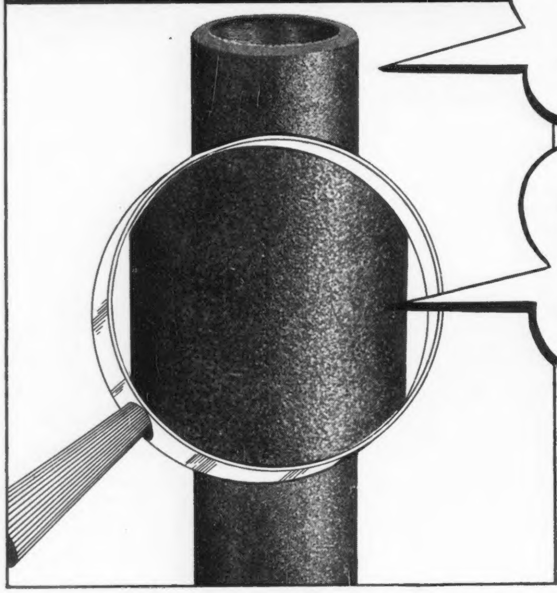
Surface Preparation in Plating Aluminum Die-Castings. *Die Casting*, **6**, No. 6, 59-62 (1948).

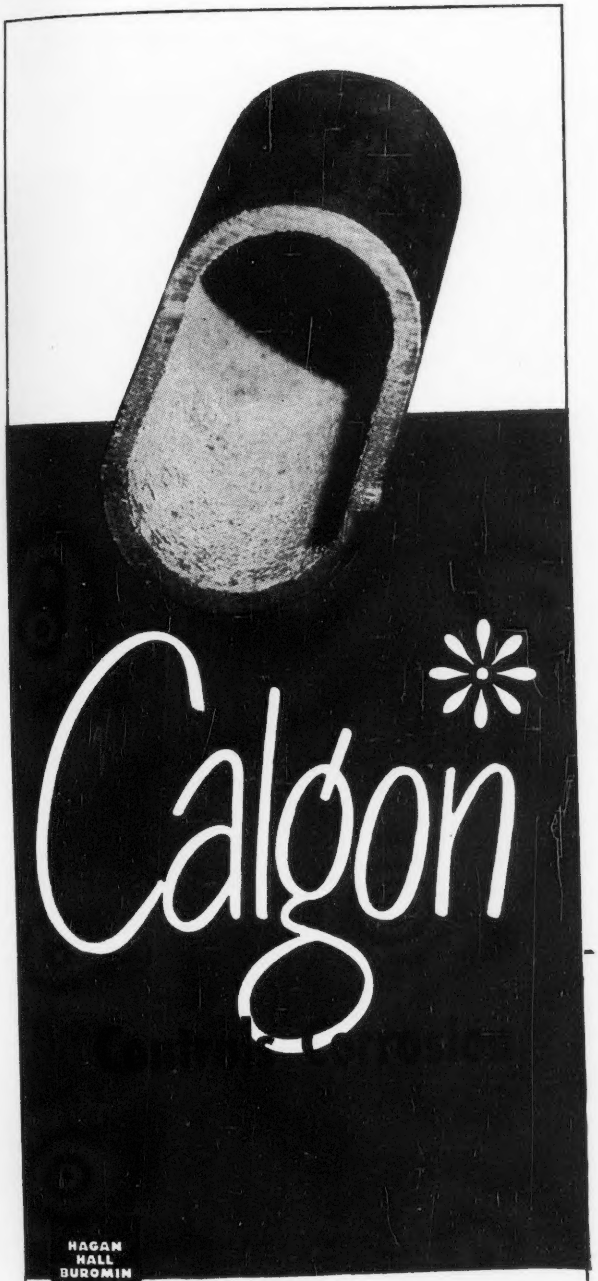
The flow sheet of plating operations for a high-silicon aluminum alloy is discussed. In sequence the steps are: cleaning; water rinse; acid pickle; water rinse; mixed-acid dip; water rinse; acid pickle; water rinse; zinc immersion treatment; water rinse; water rinse; electroplate.—MA.

CORROSION DIRECTORY

Rates for notices under this heading can be obtained from National Association of Corrosion Engineers, 919 Milam Building, Houston 2, Texas



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